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MARK VII-A FUEL SLUGS
Computer Surveillance of Crystallographic Orientation

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Introduction

Dimensional stability of natural uranium fuel slugs during irradiation is important to continuous reactor operation. Because uranium exhibits an anisotropic growth property during irradiation, a method is needed to measure crystallographic orientation of uranium in fuel slugs and to relate this to dimensional stability during irradiation.

X-ray diffraction techniques are being used routinely at the Savannah River Plant to measure the crystallographic orientation of Mark VII-A production slugs. Orientation of each of ten selected planes is compared with that which would be exhibited if crystals were oriented randomly, and a Growth Index[1,2] is calculated as a measure of the dimensional stability to be expected.

This report describes computer programs developed for data preparation, statistical analysis, and presentation of the X-ray diffraction information.

Period Covered: April 1961 through June 1962.

Summary

Natural uranium fuel slugs are produced by a controlled process and definite averages and standard deviations exist for X-ray diffraction data. A change in a production variable, such as heat treatment, is readily discernible through statistical quality control.

Programs for the IBM 1401 computer have been developed which compute the average values and 3-sigma limits for Texture Coefficient and G3 Growth Index data. This information is updated weekly and is plotted by the computer in the form of average ($\bar{X}$) and range (R) charts. Each month an Exception Report and a G3 Index are computed. These show only those charts which had $\bar{X}$ or R factors exceeding 3-sigma limits during the month.

Thus, trends are revealed in the crystallographic orientation characteristics of Savannah River Plant fuel slugs. Future work will relate orientation characteristics to reactor behavior. Study of Mark V-B data should provide test slugs of widely varying history and permit further correlation between crystallographic orientation and behavior.

Discussion

SOURCE MATERIAL

The two suppliers of canned Mark VII-A fuel slugs are the Sylvania Nuclear Corporation (SCNC) and the hot press (HP) bonding facility at the Savannah River Plant. The Savannah River Plant X-Ray Diffraction Laboratory began routine surveillance of SCNC slugs in April 1961 and of HP slugs in May 1961. Surveillance prior to these dates is not included here because of a different heat treatment then in use. Data in this report are concerned solely with Mark VII-A salt-oil beta heat treated fuel slugs, produced under current manufacturing methods.

Slugs for routine surveillance:

SCNC: 5 slugs from each shipment received.

HP: 1 slug per day, taken at random from the production line.

DIFFRACTION TECHNIQUES

From each uranium slug, two samples are prepared for X-ray diffraction analysis. One sample is examined on a surface perpendicular to the slug axis (longitudinal); the second sample is examined on a radial surface of the slug (circumferential).

A Norelco X-Ray Diffractometer is used to gather information on the 020, 110, 021, 002, 111, 112, 131, 023, 200 and 113 crystallographic planes.

The Diffractometer is run at 1° per minute scanning speed with a 1° divergence slit, a 0.006 inch wide scatter slit, and a 1° receiving slit. A copper target X-ray tube, operated at 40 kv and 40 ma, is used as the source. A nickel filter confines the beam to copper K-alpha radiation. The integrated intensities are gathered by a Geiger tube.

Basic data collected by the Diffractometer is converted into a Texture Coefficient for each of the 10 planes by the following relationship:

$$TC_i = \frac{I_i/I_{oi}}{\left(\frac{1}{10}\right)\sum_{i=1}^{10}(I_i/I_{oi})}$$

where TC_i = Texture Coefficient

I_i = Net Peak Intensity (excluding background)

I_{oi} = Random Intensities for Uranium[3]

An Area Weight Growth Index (G3) for the 10-plane case is also calculated. The formula is:

$$G3 = \frac{\sum_{i=1}^{10}(Awi)(I_i/I_{oi})(\cos^2\beta i - \cos^2\gamma i)}{\sum_{i=1}^{10}(Awi)(I_i/I_{oi})}$$

where G3 = Area Weight Growth Index[3]

Awi = Area Weight Factor[4]

γi and βi = Angles the i plane makes with the γ and β crystallographic axes, respectively.

DATA ANALYSIS

To analyze the Area Weight Growth Index (G3) of these production slugs, $\bar{X}$ (average) and R (range) charts[5] were constructed. $\bar{X}$ is the arithmetic mean of four sequential samples, and R is the difference between the largest and smallest value in a group of four.

Previous histograms of the data strongly indicated the possibility of an inherent statistical control operating within the production system. It was therefore anticipated that a quality control approach would allow variabilities in the system which exceeded 3-sigma limits to be explained.

The first construction of the $\bar{X}$ and R charts for G3 (calculated manually) did in fact indicate a noticeable difference in the HP slugs produced prior to May 1961 (see figure 1). A subsequent check indicated these prior slugs had been produced using a bronze-tin heat treatment rather than an oil-quench heat treatment.

With this indication of a system under statistical control, further exploration using the Texture Coefficient (TC) data was warranted. The mass of data available dictated that a computer be used for the analysis. A program for the IBM 1401 computer was prepared.

Use of a computer was logical because of the increased speed and timeliness, and because TC and G3 data, calculated for each sample diffracted, were already in a computer system. Therefore, for the further $\bar{X}$ and R analysis, output from the TC and G3 computations was used; input required very little human preparation.

Several months were required for formulating and testing the programing package. Conversion of IBM 650 data, computed prior to March 1962, was necessary so that the data would be compatible with the current FORTRAN TC and G3 programs. The converted data and current data were used to check the IBM 1401 Autocoder program which calculates and plots $\bar{X}$ and R information.

Computer running time for the $\bar{X}$ and R program, including graph copies necessary for reporting, is less than one-half hour. An additional benefit derived from this program is the availability of an up-to-date magnetic tape file of all X-ray preferred orientation data from which other reports and computations can easily be made.

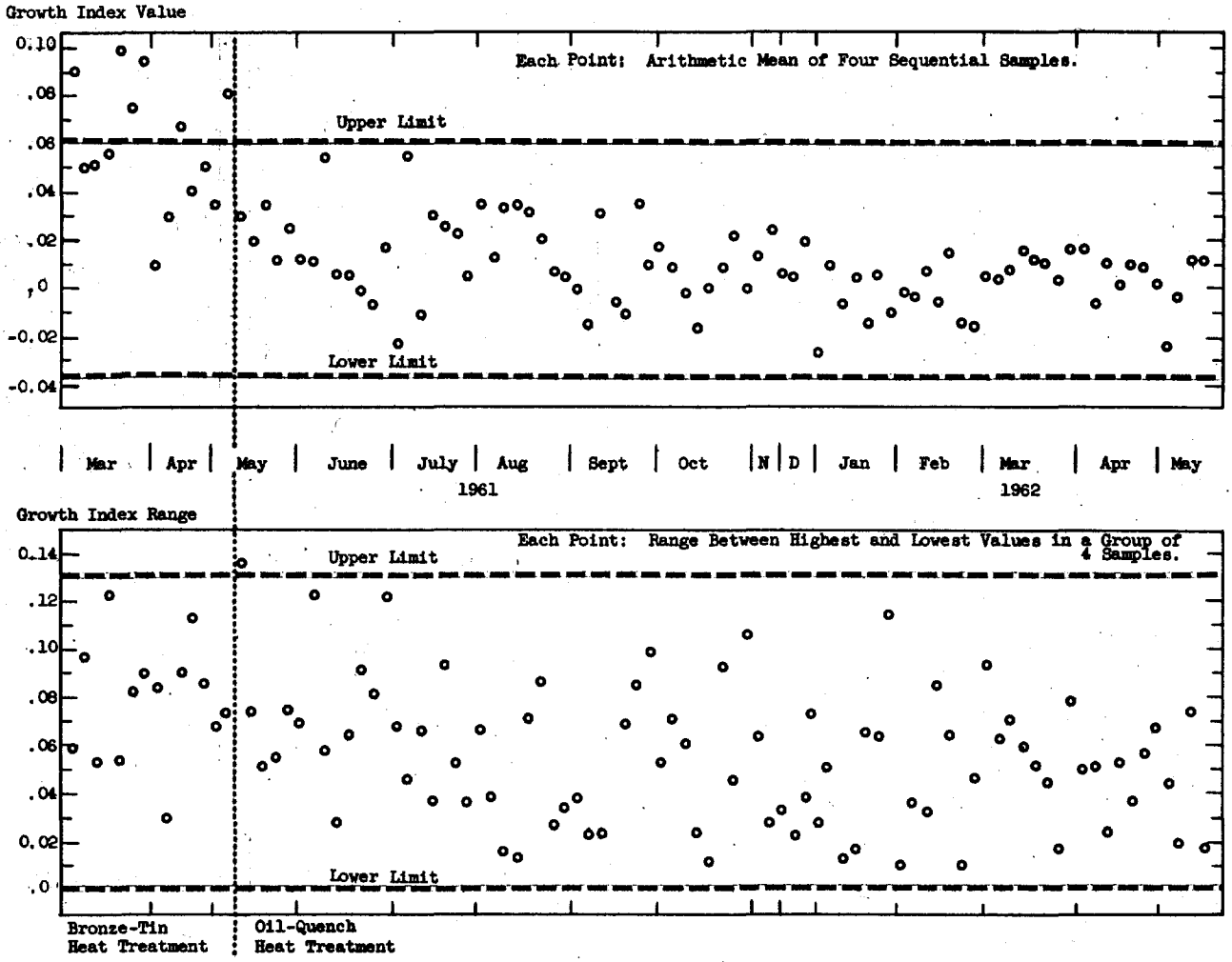


FIGURE 1. G3 AREA WEIGHT GROWTH INDEX, CIRCUMFERENTIAL SAMPLES, MARK VII-A HP PRODUCTION SLUGS.

ANALYSIS OF COMPUTER OUTPUT

The system used to handle data from the X-ray diffractometer appears in figure 2. Data from the diffractometer is copied onto raw data sheets by a technician. Currently, one technician is diffracting between 250 and 300 samples per month, and in addition is handling the sample etching and the uranium inventory matters.

The raw data sheets are forwarded to a card punch group where information is punched into IBM cards. Four IBM cards are necessary for each raw data sheet. The cards are then fed into a computer where the following functions are performed:

(1) All raw data cards which were obviously out of sequence (the four raw data cards are numbered sequentially) are returned to be corrected.
(2) All raw data cards for samples whose TC's or G3 exceeded 3-sigma limits (determined by previous experience) are returned for checking, along with a finished data card containing the TC and G3 values.
(3) Finished data cards (TC and G3) are returned for all other samples.
(4) Concurrent with the return of the finished data cards, a data listing is made.

A time delay is built into the computation system at this point so that X-ray laboratory personnel can check the data and correct it as necessary. When all samples which exceeded 3-sigma limits have been checked, and necessary corrections have been made to raw data, the raw data cards that were returned during the first computer run are reprocessed along with finished data cards from the first computer run. The master magnetic tape file is then updated. Concurrent with the updating of the magnetic tape file, $\bar{X}$ and R charts are computed and plotted by the computer. One complete set of $\bar{X}$ and R charts is printed for laboratory use; an abbreviated set (the Exception Report) is printed along with its index for reporting purposes. These monthly Exception Reports contain only those charts which, since the last report, had either $\bar{X}$ or R factors exceeding 3-sigma limits.

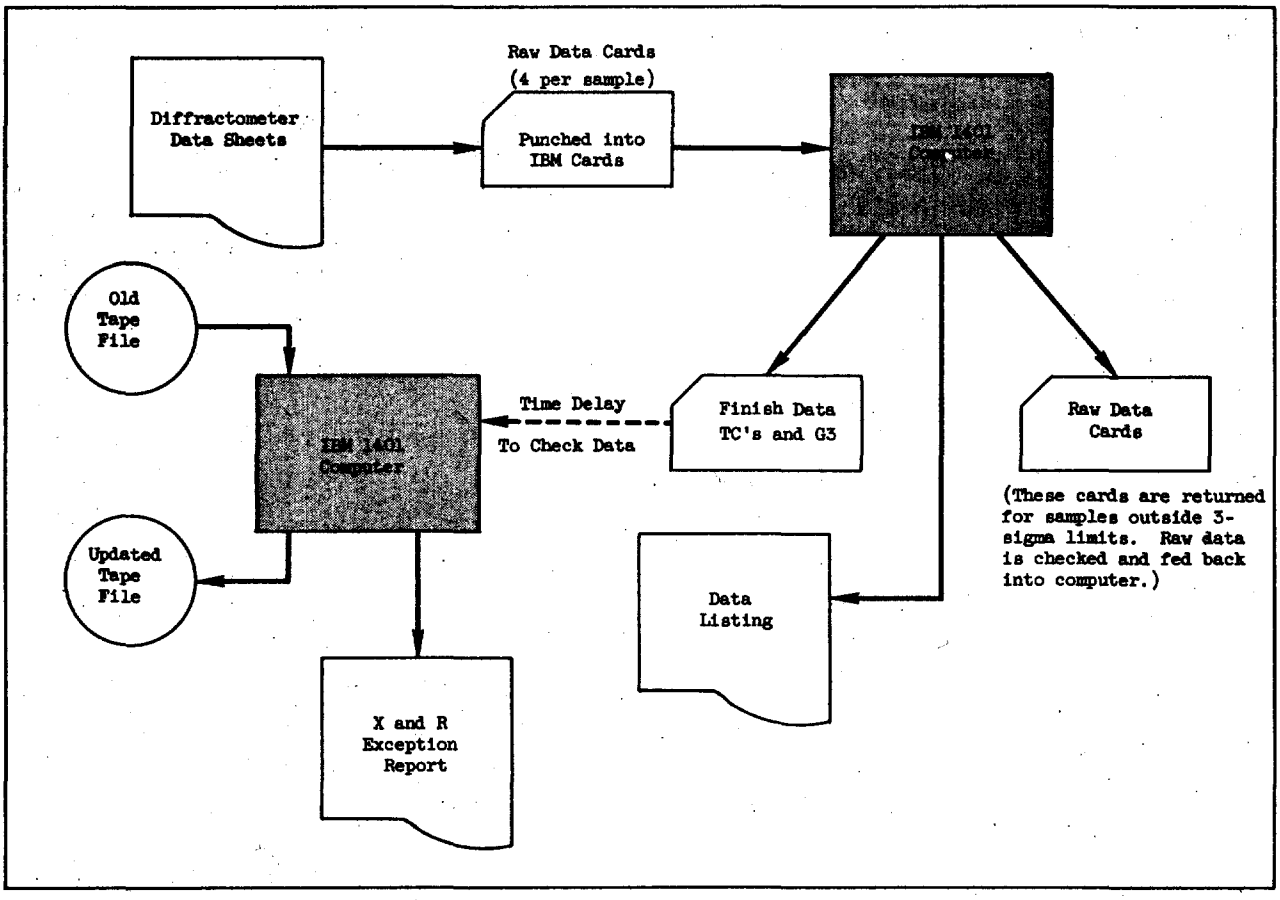


FIGURE 2. X-RAY DIFFRACTION DATA FLOW CHART

PERIODIC REPORTS

The appendix contains charts that show the Savannah River Plant's $\bar{X}$ and R experience through June 30, 1962. The charts show longitudinal and circumferential orientation data for Mark VII-A slugs of salt-oil beta heat-treated natural uranium. The charts represent 742 HP and 734 SCNC samples.

Figure 3 is an example of an Exception Report index page.

Figure 4 is an example of the finished data used to calculate the $\bar{X}$ and R charts. The X-ray laboratory has complete copies of all diffraction data discussed in this report and can make copies available to interested parties.

References

1. Sturcken, E. F., An X-Ray Method for Predicting the Stability of Natural Uranium at Low Burnup, DP-251, November 1957.

2. Permar, P. H., letter to Hood Worthington, Correlation of Anisotropic Growth of Unrestrained Uranium With Preferred Orientation By the Growth Index Concept. June 11, 1962.

3. Morris, P. R., ed, USAEC Report NLCO-804, National Lead Company, Cincinnati, Ohio.

4. Morris, P. R., ed, USAEC Report NLCO-764, National Lead Company, Cincinnati, Ohio.

5. Grant, E. L., Statistical Quality Control. New York, McGraw-Hill Book Company, 1952.

7JUL62 EXCEPTION REPORT
SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A HP & SCNC ROUTINE PRODUCTION SLUGS

ATTACHED ARE ALL TEXTURE COEFFICIENT CONTROL CHARTS WHICH, SINCE THE LAST REPORT, EXCEEDED 3-SIGMA PRODUCTION CONTROL LIMITS. ASTERISKS ARE USED TO INDICATE ANY POINT WHICH WAS OUT OF LIMITS.
ALSO ATTACHED ARE ALL G3 AREA WEIGHT GROWTH INDEX CONTROL CHARTS.

PRODUCTION SOURCE	TYPE SAMPLE	TEXTURE OR G3	EXCEEDED 3-SIGMA LIMITS R	EXCEEDED 3-SIGMA LIMITS X	REPORT PAGE
HP	LONGITUDINAL	002	YES	NO	001
HP	LONGITUDINAL	112	YES	YES	002
HP	LONGITUDINAL	G3	NO	NO	003
HP	CIRCUMFERENTIAL	021	NO	YES	004
HP	CIRCUMFERENTIAL	002	YES	NO	005
HP	CIRCUMFERENTIAL	111	YES	YES	006
HP	CIRCUMFERENTIAL	G3	NO	NO	007
SCNC	LONGITUDINAL	020	NO	YES	008
SCNC	LONGITUDINAL	023	YES	YES	009
SCNC	LONGITUDINAL	G3	NO	NO	010
SCNC	CIRCUMFERENTIAL	111	YES	YES	011
SCNC	CIRCUMFERENTIAL	112	YES	NO	012
SCNC	CIRCUMFERENTIAL	131	NO	YES	013
SCNC	CIRCUMFERENTIAL	200	YES	NO	014
SCNC	CIRCUMFERENTIAL	G3	NO	NO	015

FIGURE 3. SAMPLE INDEX PAGE FROM AN EXCEPTION REPORT

SAVANNAH RIVER PLANT
PREFERRED ORIENTATION DATA TAPE REPORT

JULY 7, 1962

REQ	LOG NO	DR	MCH	CRYSTALLOGRAPHIC PLANE TEXTURE 020	110	021	002	111	112	131	023	200	113	G3
83	1298	1	2	1.00	0.79	0.88	1.00	0.88	0.91	0.91	1.36	1.19	1.11	0.011
83	1298	2	1	0.67	0.90	0.84	0.69	0.96	1.00	1.02	1.08	1.92	0.97	-0.053
83	1299	1	2	1.19	0.75	0.65	0.74	0.80	0.77	0.93	1.79	1.28	1.16	0.023
83	1299	2	2	0.82	0.90	0.75	0.78	0.88	0.85	1.27	1.38	1.38	1.03	0.009
83	1300	1	2	1.34	0.90	0.88	0.77	0.87	0.87	0.94	0.85	1.71	0.91	-0.005
83	1300	2	1	1.42	0.81	0.74	0.95	1.01	0.96	0.76	1.10	1.25	1.04	-0.008
83	1301	1	1	1.18	0.67	0.76	0.93	0.74	0.88	1.09	1.41	0.97	1.41	0.045
83	1301	2	2	1.68	0.81	0.97	0.77	0.83	0.89	1.51	0.95	0.62	1.03	0.109
82	1302	1	2	0.94	0.83	0.63	1.05	0.90	0.75	1.01	1.43	1.44	1.09	-0.012
82	1302	2	2	1.40	0.74	0.75	0.83	0.75	0.88	0.96	0.97	1.36	1.39	0.016
59	1303	1	1	0.86	0.86	0.73	0.96	0.90	1.03	1.08	1.23	1.19	1.19	-0.010
59	1303	2	2	1.32	0.78	0.74	0.80	0.84	0.77	1.16	1.38	1.28	0.96	0.042
59	1304	1	2	1.02	0.75	0.84	0.99	0.74	0.87	0.92	1.29	1.34	1.30	0.011
59	1304	2	1	0.98	0.88	0.62	0.94	0.84	0.92	0.93	1.20	1.70	1.05	-0.037
59	1305	1	1	1.24	0.86	0.75	0.99	0.72	0.81	1.07	1.19	1.55	0.87	0.024
59	1305	2	2	1.01	0.86	0.73	1.03	0.92	0.83	1.15	1.24	1.10	1.18	0.013
59	1306	1	2	1.17	0.71	0.83	0.76	0.80	0.92	1.04	1.26	1.24	1.32	0.025
59	1306	2	1	1.46	0.93	0.87	0.73	0.88	0.83	1.04	1.36	0.98	0.98	0.052
59	1307	1	2	0.87	0.78	0.81	0.72	1.01	1.07	0.98	1.48	1.12	1.19	-0.006
59	1307	2	2	1.21	0.94	0.83	0.91	0.88	0.86	1.03	1.26	1.10	1.02	0.025
59	1308	1	1	1.32	0.91	0.76	0.94	0.89	0.88	1.06	1.18	1.08	1.02	0.026
59	1308	2	2	1.44	0.77	0.67	1.04	0.88	0.90	0.88	1.26	1.19	1.01	0.018
59	1309	1	2	1.37	0.87	0.72	1.00	0.79	0.76	1.00	1.19	1.34	1.00	0.025
59	1309	2	2	1.15	0.84	0.74	0.85	0.81	0.92	1.03	1.27	1.46	0.97	0.009
59	1310	1	2	1.08	0.85	0.85	1.33	0.70	0.75	0.99	1.40	1.21	0.90	0.039
59	1310	2	1	1.04	1.00	0.71	0.09	0.93	0.85	0.96	1.41	1.93	1.11	-0.040
59	1311	1	1	1.13	0.66	0.75	1.13	0.77	0.77	0.90	1.31	1.59	1.04	0.009
59	1311	2	2	1.48	0.99	0.78	0.56	0.89	1.06	1.07	1.09	1.14	1.00	0.023
59	1312	1	2	0.84	0.72	0.84	0.97	0.76	0.88	0.98	1.37	1.58	1.11	-0.001
59	1312	2	2	1.06	0.91	0.83	0.82	0.92	1.03	0.96	1.13	1.33	1.07	-0.011

FIGURE 4. SAMPLE OF DATA USED TO CALCULATE $\bar{X}$ AND R CHARTS.
The numbers below the crystallographic plane textures refer to Miller plane indices.

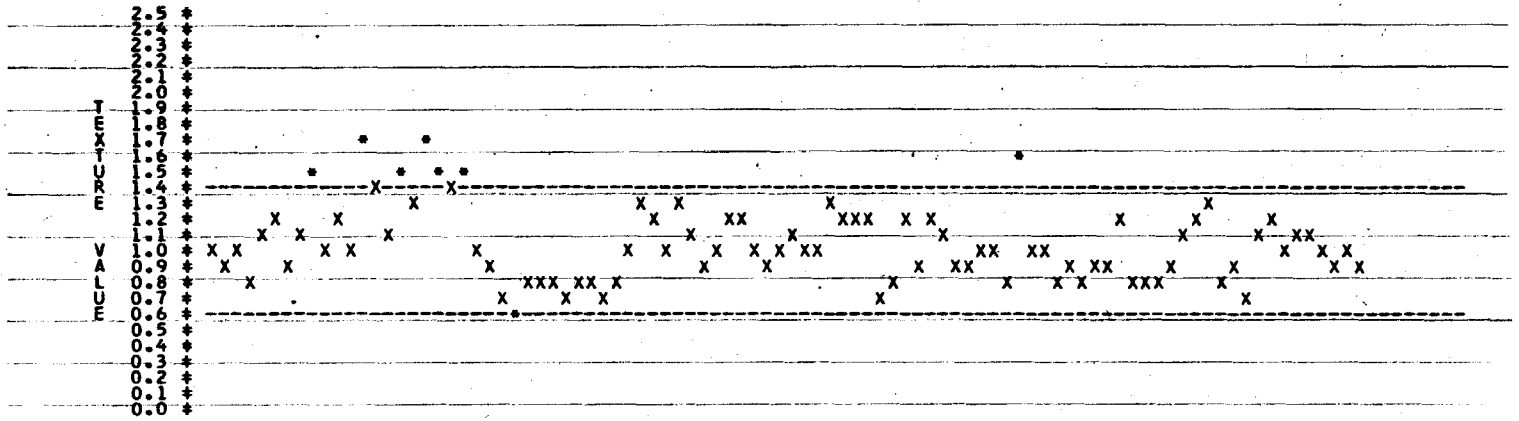
LEGEND

REQ - Material identification (laboratory)
LOG - Sample log No. (one per slug)
NO - Individual sample No.
DR - Sample direction: 1, longitudinal; 2, circumferential
MCH - Diffractometer No.
G3 - Area weight growth index

Appendix

Appendix

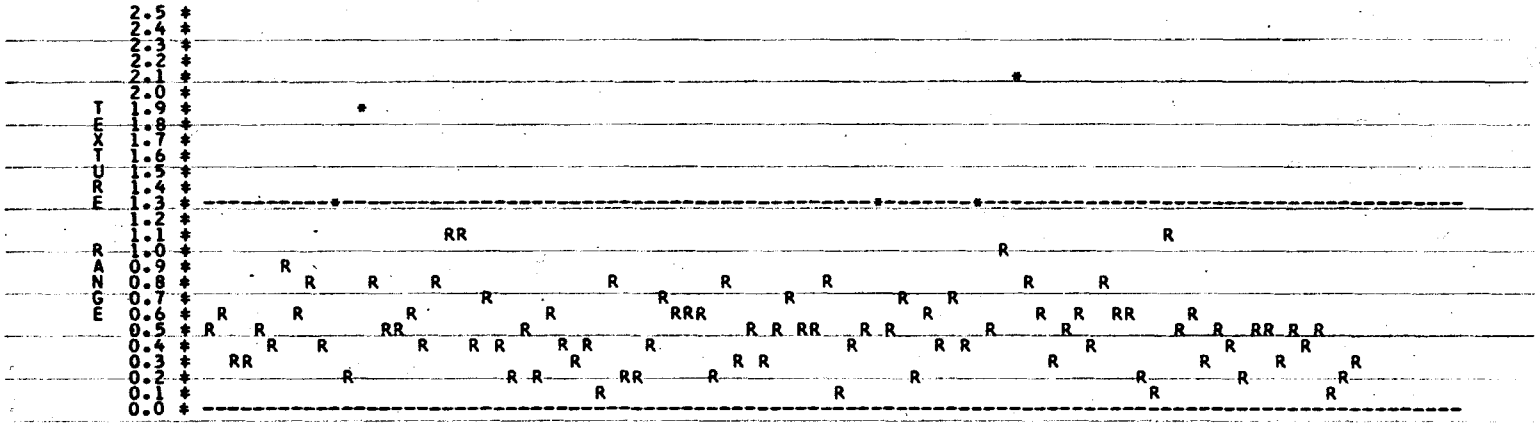
SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A HP ROUTINE PRODUCTION SLUGS
020 CRYSTALLOGRAPHIC PLANE TEXTURE
LONGITUDINAL DIRECTION SAMPLES



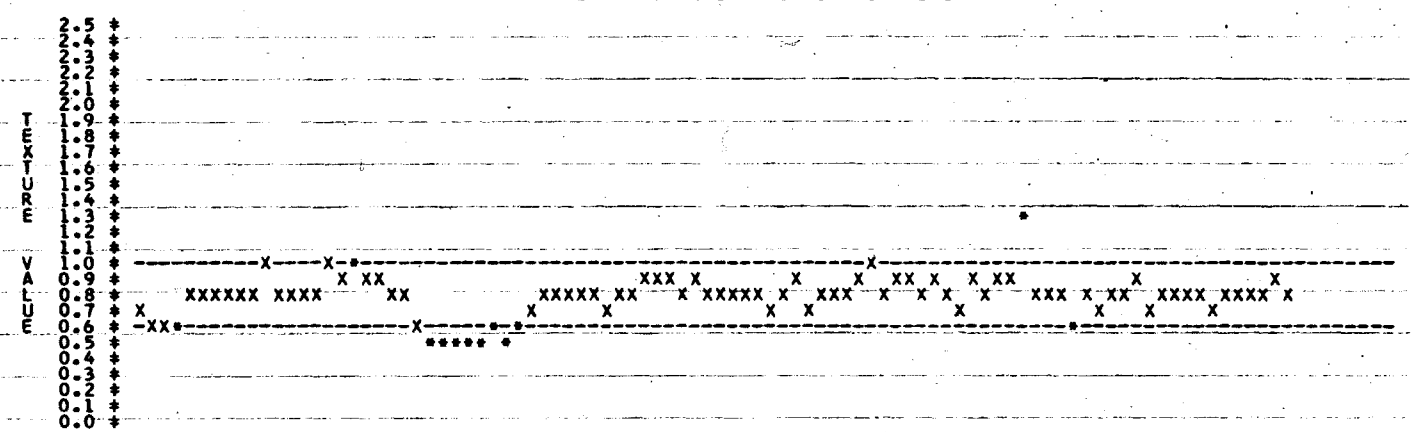
X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES

MAY 61 JUN 61 JUL 61 AUG 61 SEP 61 OCT 61 NOV 61 DEC 61 JAN 62 FEB 62 MAR 62 APR 62 MAY 62 JUN 62 JUL 62

R IS THE RANGE BETWEEN THE HIGHEST AND LOWEST VALUES IN A GROUP OF FOUR SAMPLES



SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A HP ROUTINE PRODUCTION SLUGS
110 CRYSTALLOGRAPHIC PLANE TEXTURE
LONGITUDINAL DIRECTION SAMPLES



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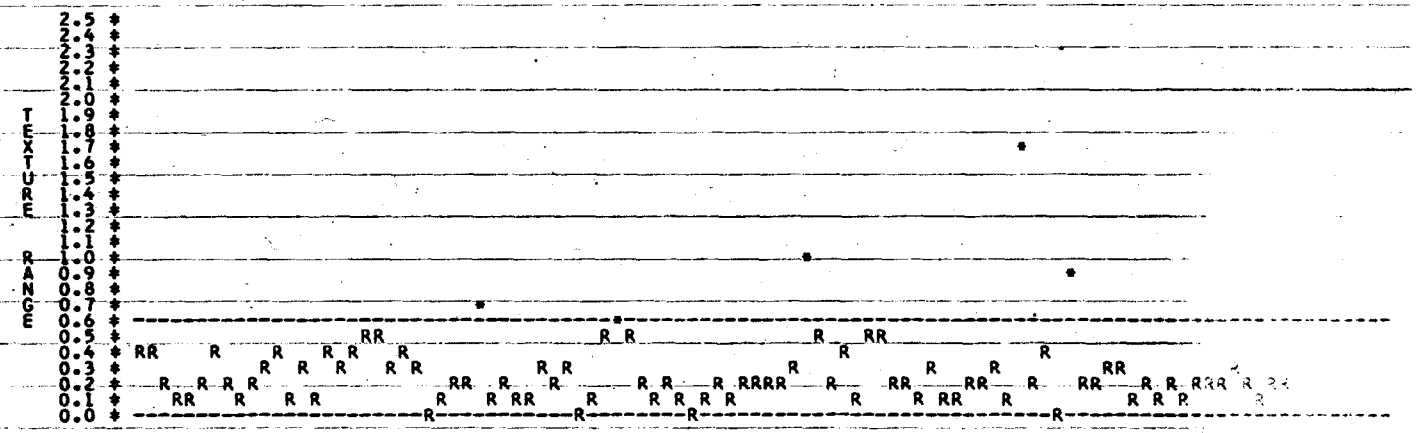
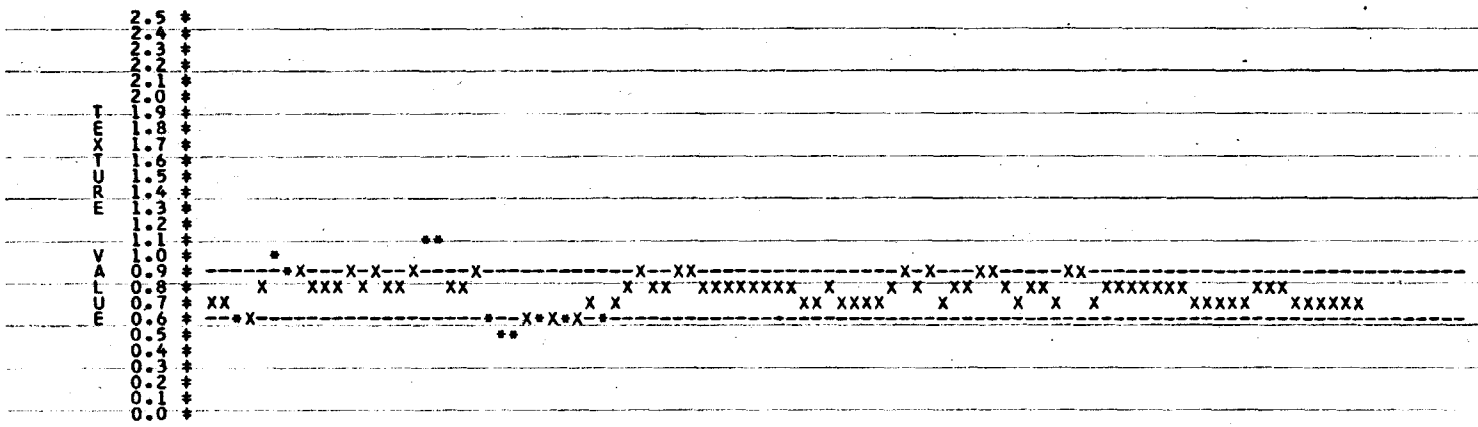


SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A HP ROUTINE PRODUCTION SLUGS
021 CRYSTALLOGRAPHIC PLANE TEXTURE
LONGITUDINAL DIRECTION SAMPLES



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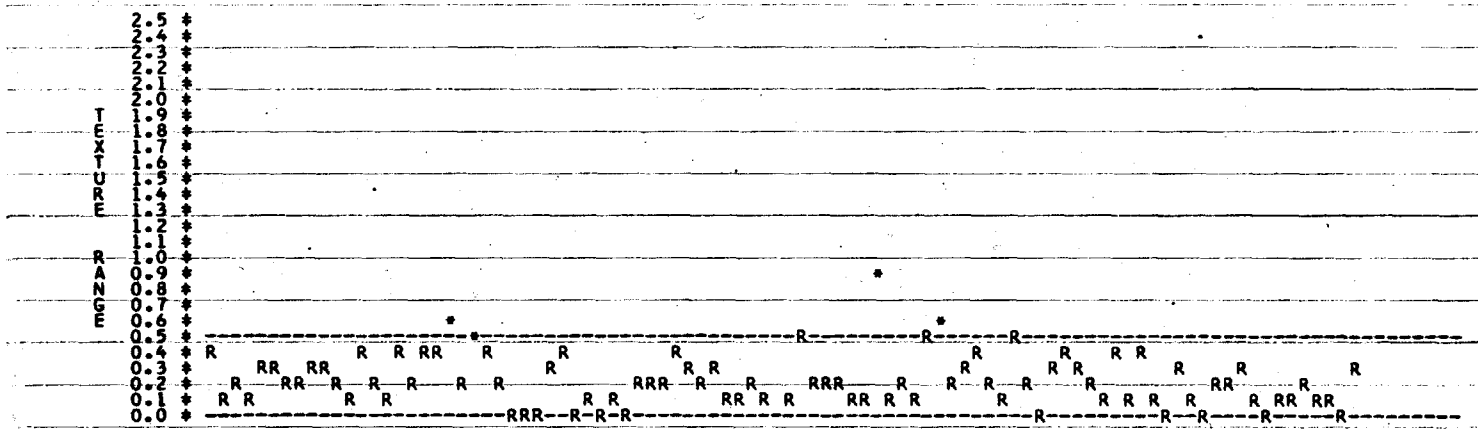
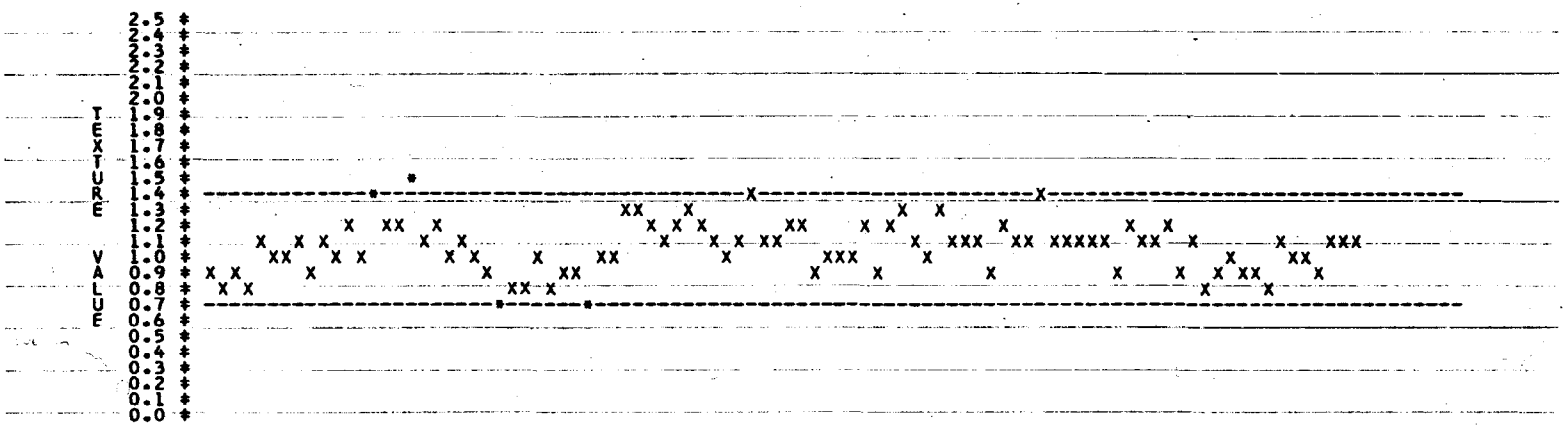


SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A HP ROUTINE PRODUCTION SLUGS
002 CRYSTALLOGRAPHIC PLANE TEXTURE
LONGITUDINAL DIRECTION SAMPLES



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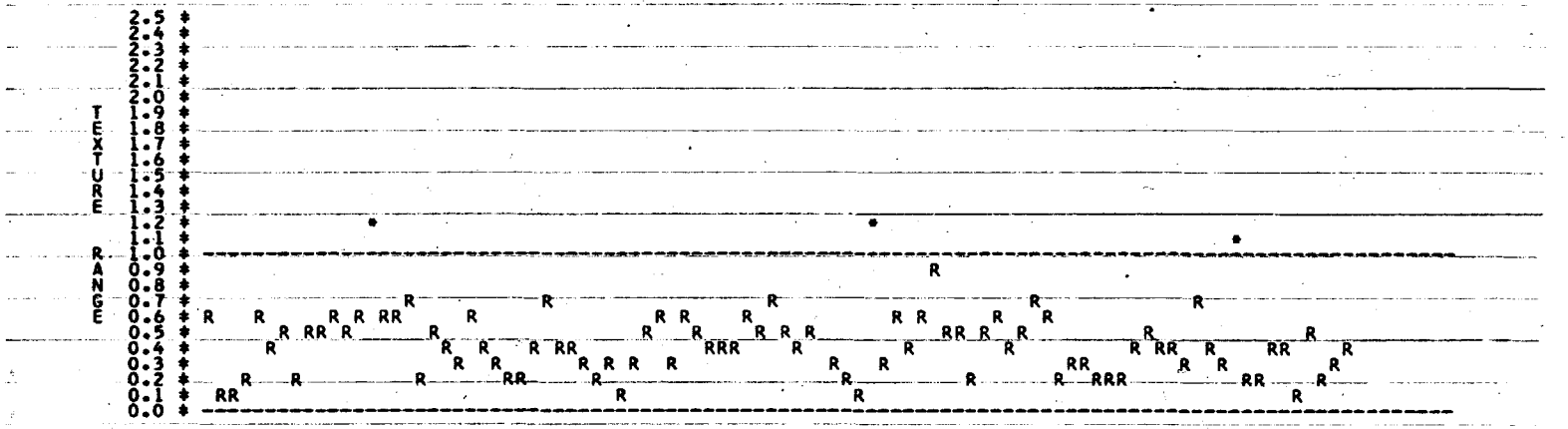
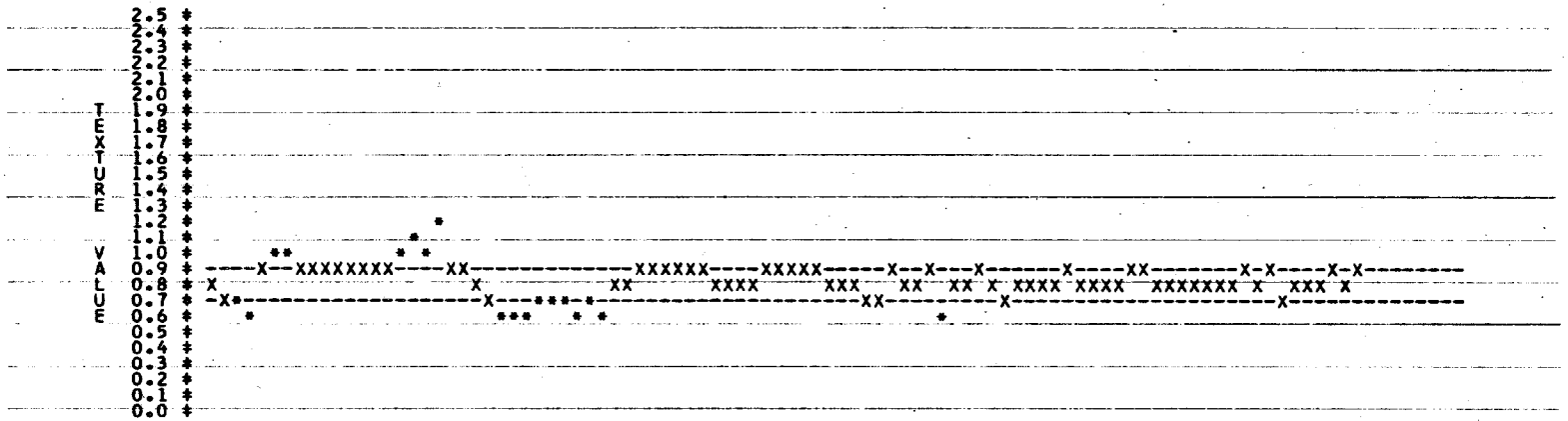


SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A HP ROUTINE PRODUCTION SLUGS
111 CRYSTALLOGRAPHIC PLANE TEXTURE
LONGITUDINAL DIRECTION SAMPLES



X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES

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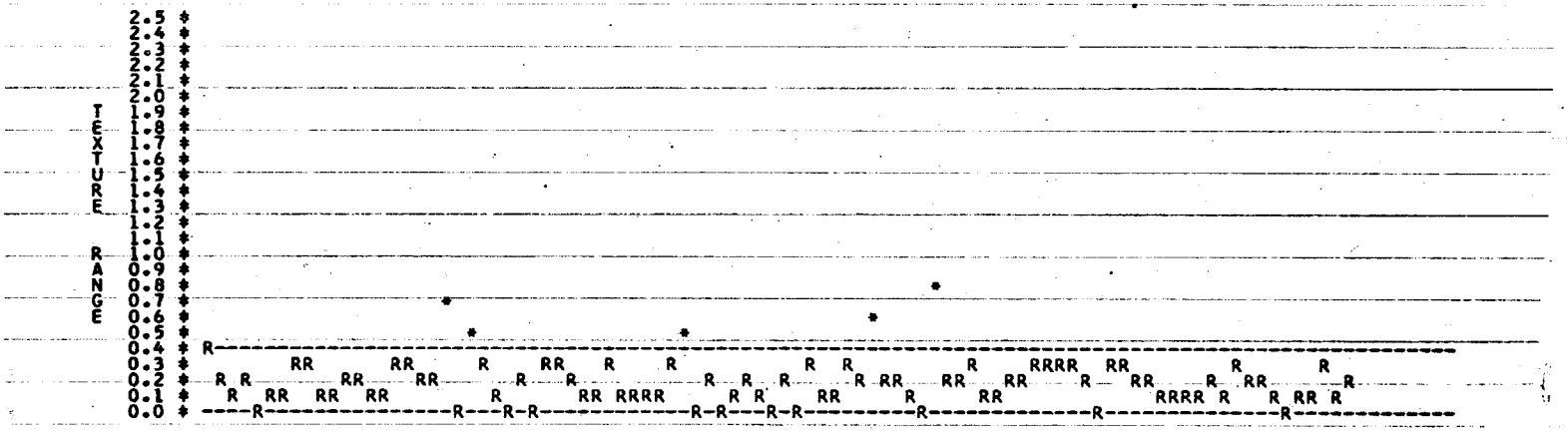
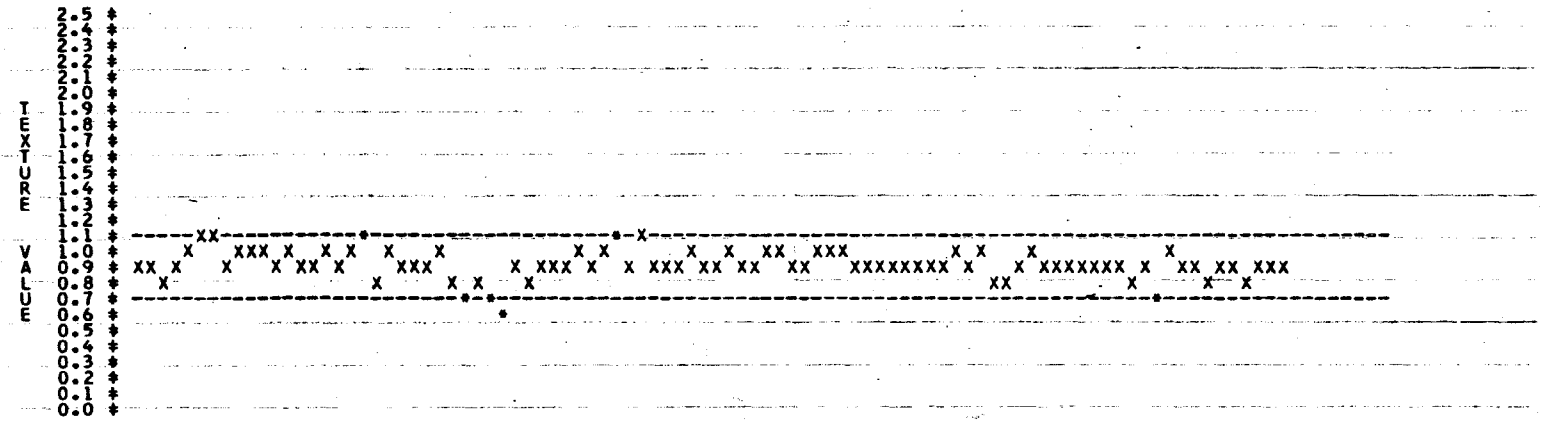


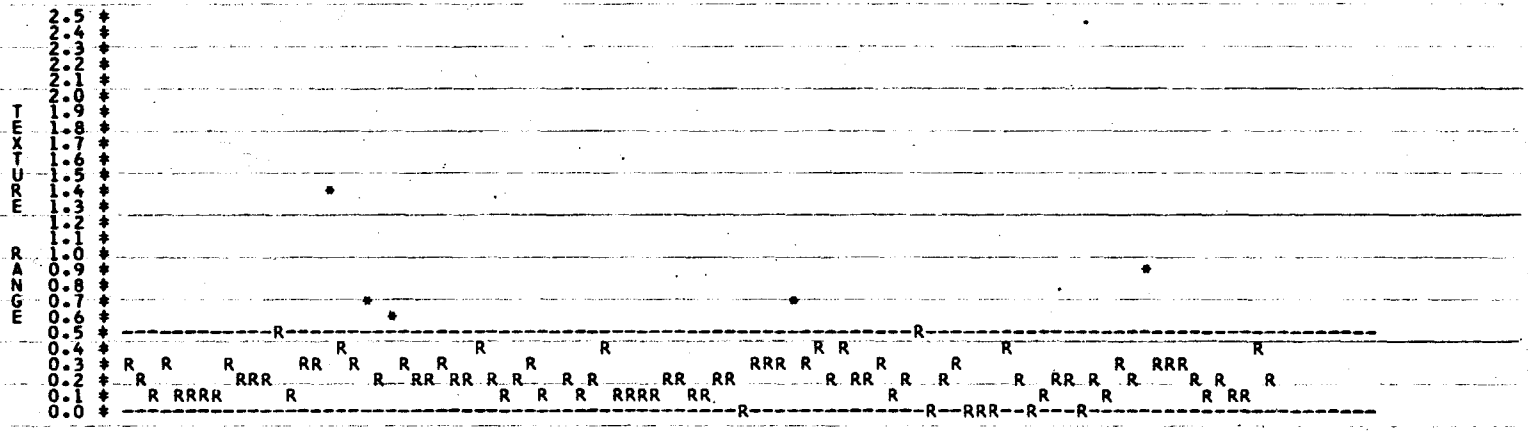
SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A HP ROUTINE PRODUCTION SLUGS
112 CRYSTALLOGRAPHIC PLANE TEXTURE
LONGITUDINAL DIRECTION SAMPLES



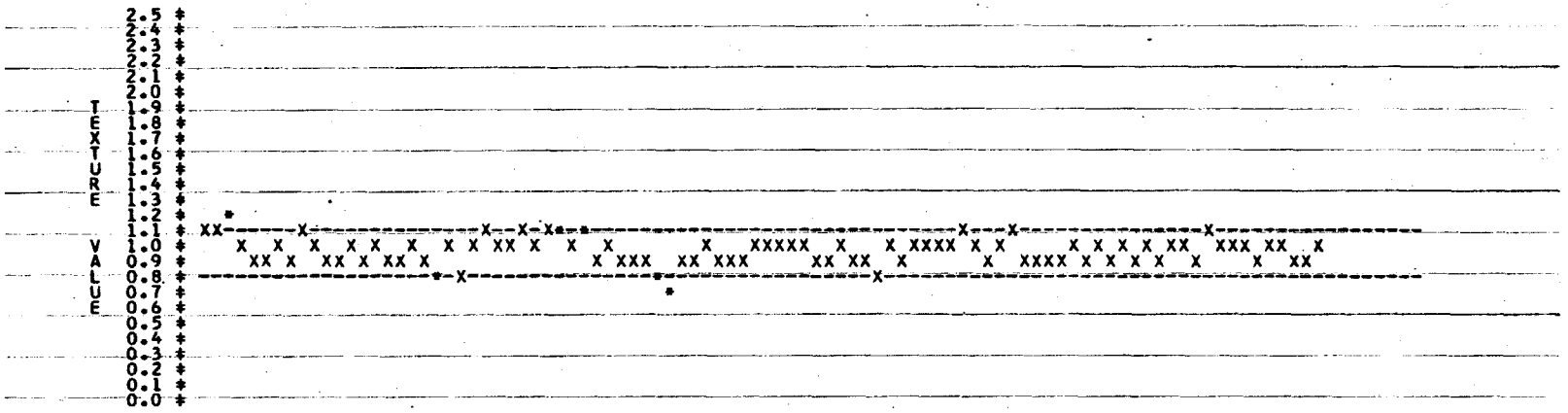
X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES

MAY 61 JUN 61 JUL 61 AUG 61 SEP 61 OCT 61 NOV 61 DEC 61 JAN 62 FEB 62 MAR 62 APR 62 MAY 62 JUN 62 JUL 62

R IS THE RANGE BETWEEN THE HIGHEST AND LOWEST VALUES IN A GROUP OF FOUR SAMPLES



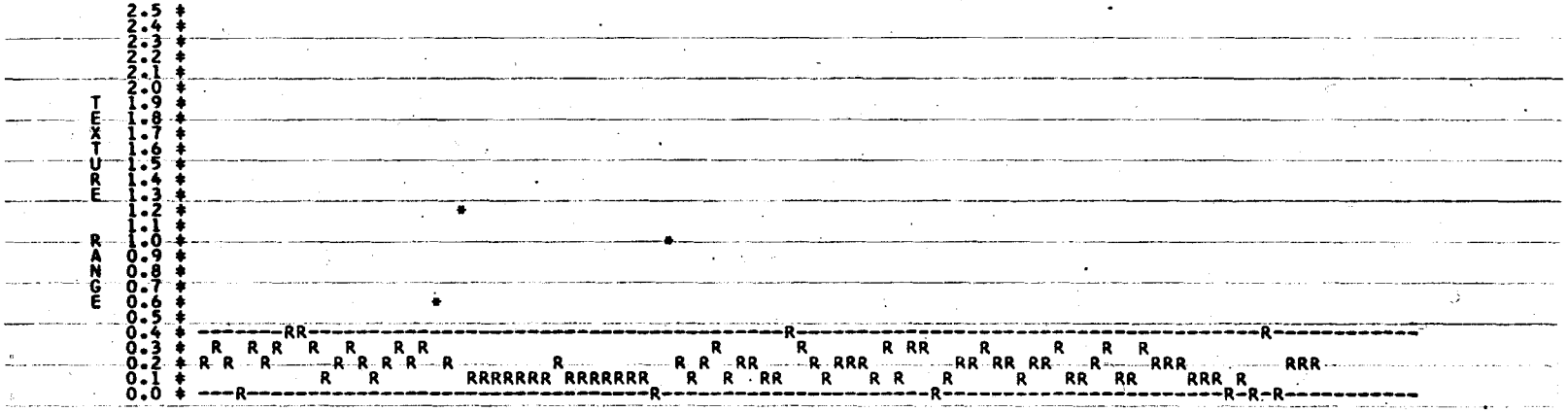
SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A HP ROUTINE PRODUCTION SLUGS
131 CRYSTALLOGRAPHIC PLANE TEXTURE
LONGITUDINAL DIRECTION SAMPLES



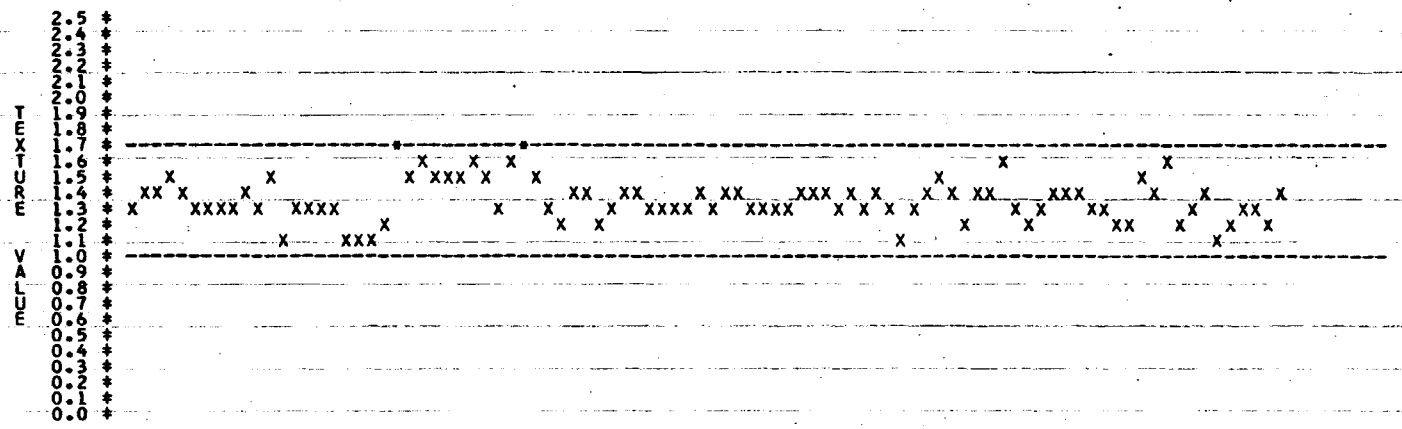
X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES

MAY 61 JUN 61 JUL 61 AUG 61 SEP 61 OCT 61 NOV 61 DEC 61 JAN 62 FEB 62 MAR 62 APR 62 MAY 62 JUN 62 JUL 62

R IS THE RANGE BETWEEN THE HIGHEST AND LOWEST VALUES IN A GROUP OF FOUR SAMPLES



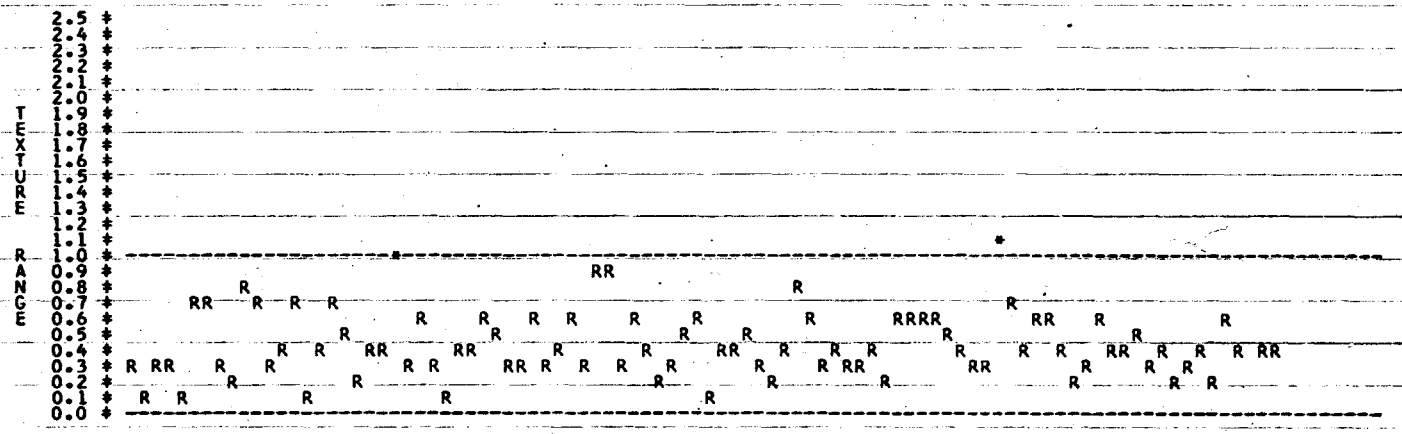
SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A HP ROUTINE PRODUCTION SLUGS
023 CRYSTALLOGRAPHIC PLANE TEXTURE
LONGITUDINAL DIRECTION SAMPLES



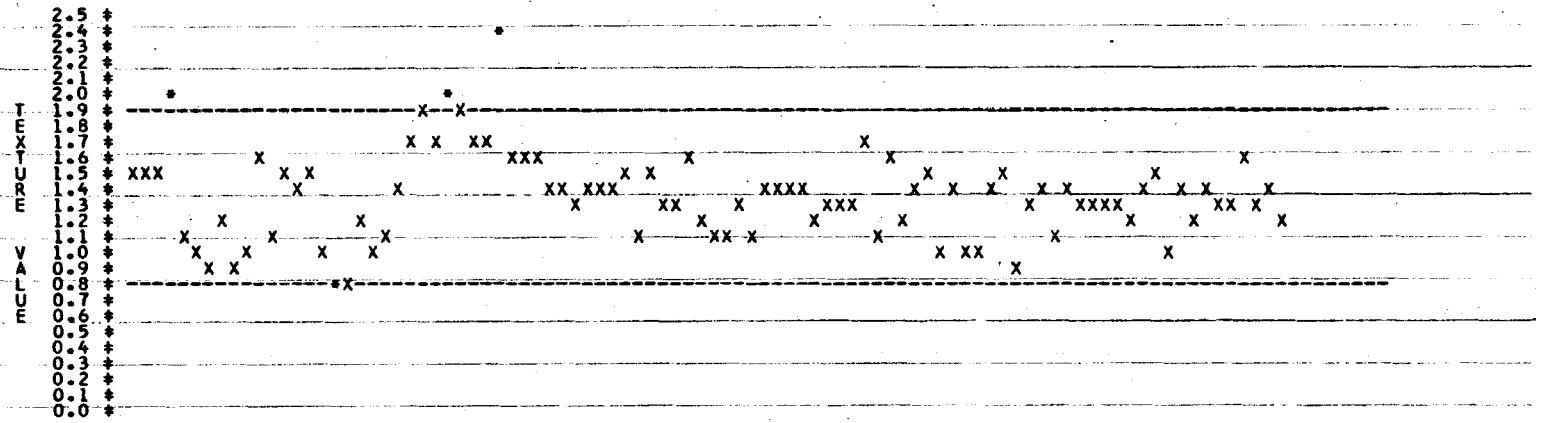
X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES

MAY61 JUN61 JUL61 AUG61 SEP61 OCT61 NOV61 DEC61 JAN62 FEB62 MAR62 APR62 MAY62 JUN62 JUL62

R IS THE RANGE BETWEEN THE HIGHEST AND LOWEST VALUES IN A GROUP OF FOUR SAMPLES



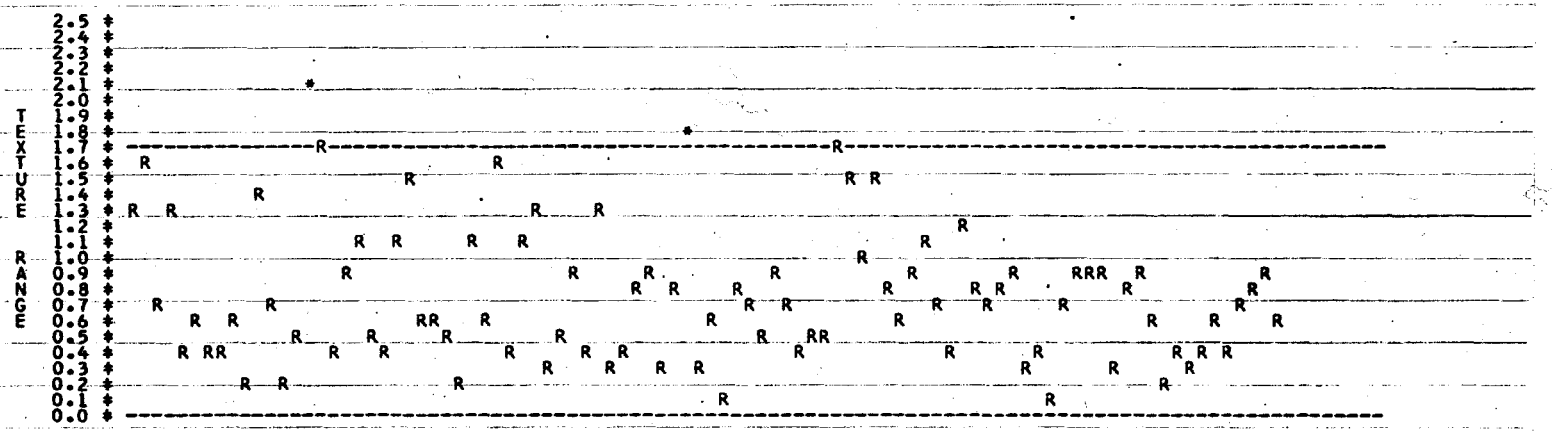
SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A HP ROUTINE PRODUCTION SLUGS
200 CRYSTALLOGRAPHIC PLANE TEXTURE
LONGITUDINAL DIRECTION SAMPLES



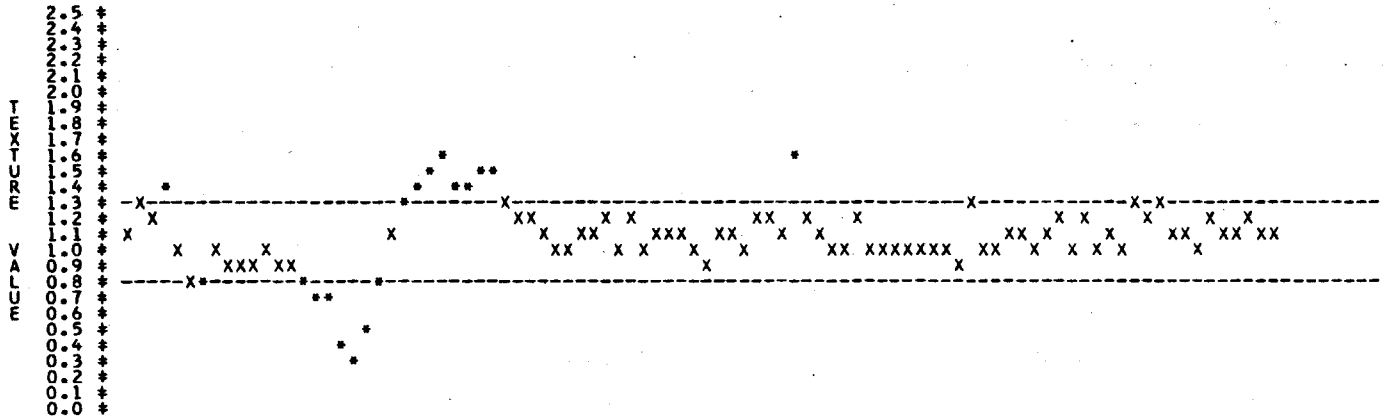
X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES

MAY 61 JUN 61 JUL 61 AUG 61 SEP 61 OCT 61 NOV 61 DEC 61 JAN 62 FEB 62 MAR 62 APR 62 MAY 62 JUN 62 JUL 62

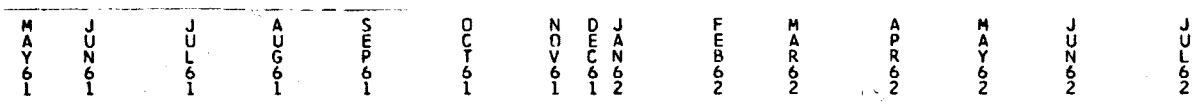
R IS THE RANGE BETWEEN THE HIGHEST AND LOWEST VALUES IN A GROUP OF FOUR SAMPLES



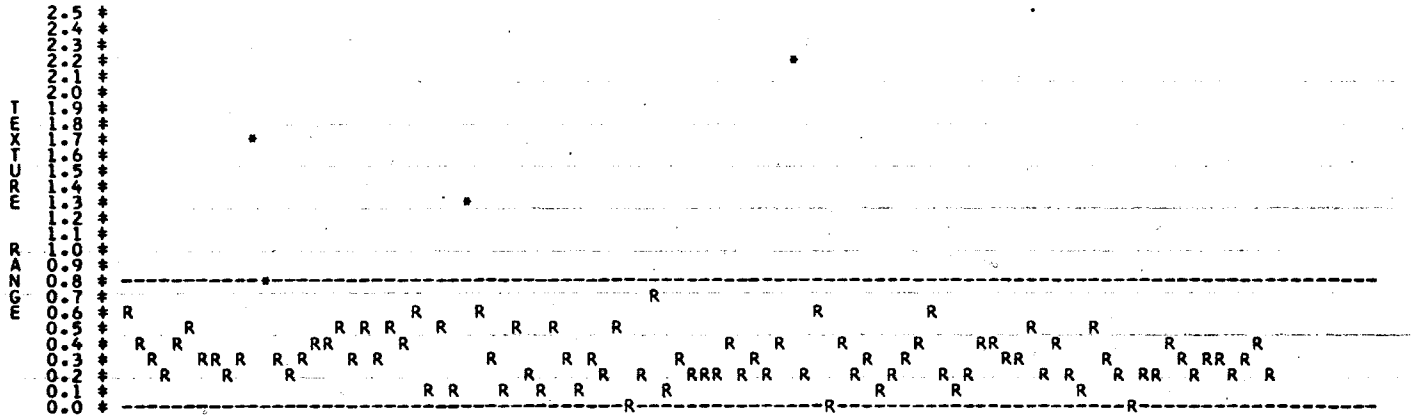
SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A HP ROUTINE PRODUCTION SLUGS
113 CRYSTALLOGRAPHIC PLANE TEXTURE
LONGITUDINAL DIRECTION SAMPLES



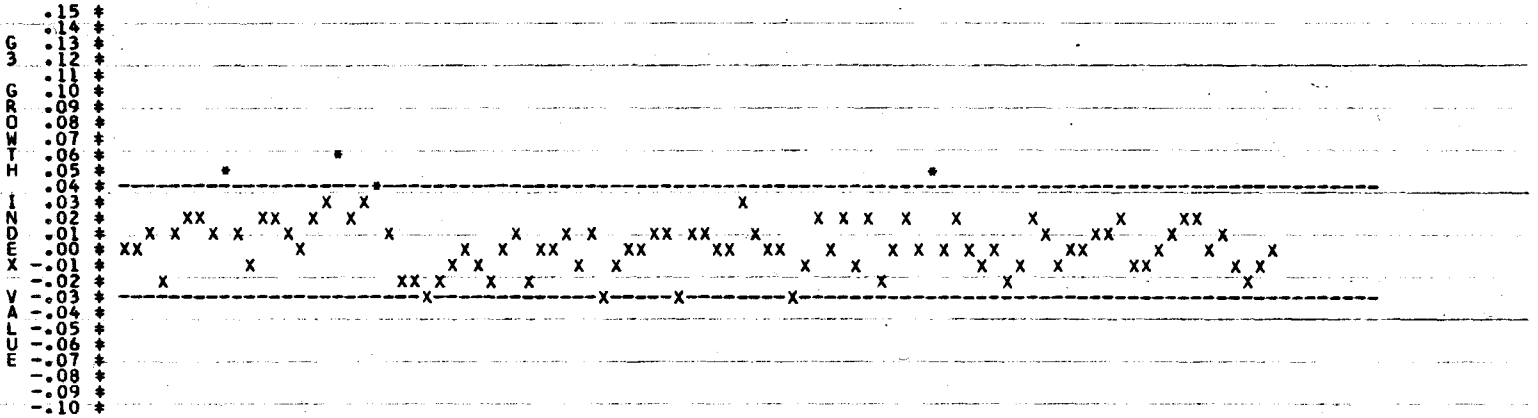
X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES



R IS THE RANGE BETWEEN THE HIGHEST AND LOWEST VALUES IN A GROUP OF FOUR SAMPLES



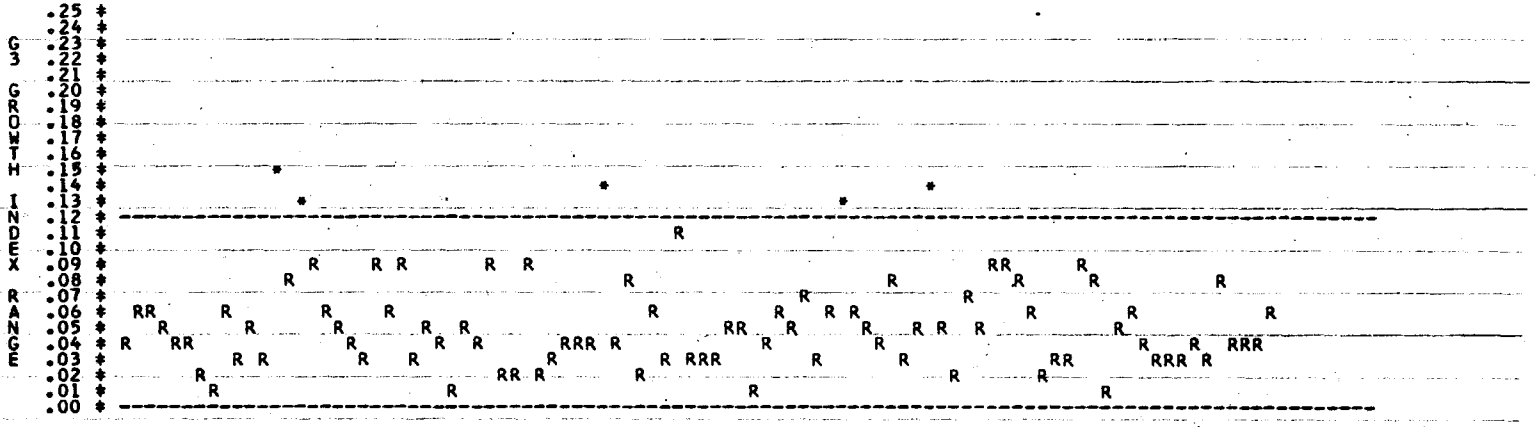
SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A HP ROUTINE PRODUCTION SLUGS
G3 AREA WEIGHT GROWTH INDEX
LONGITUDINAL DIRECTION SAMPLES



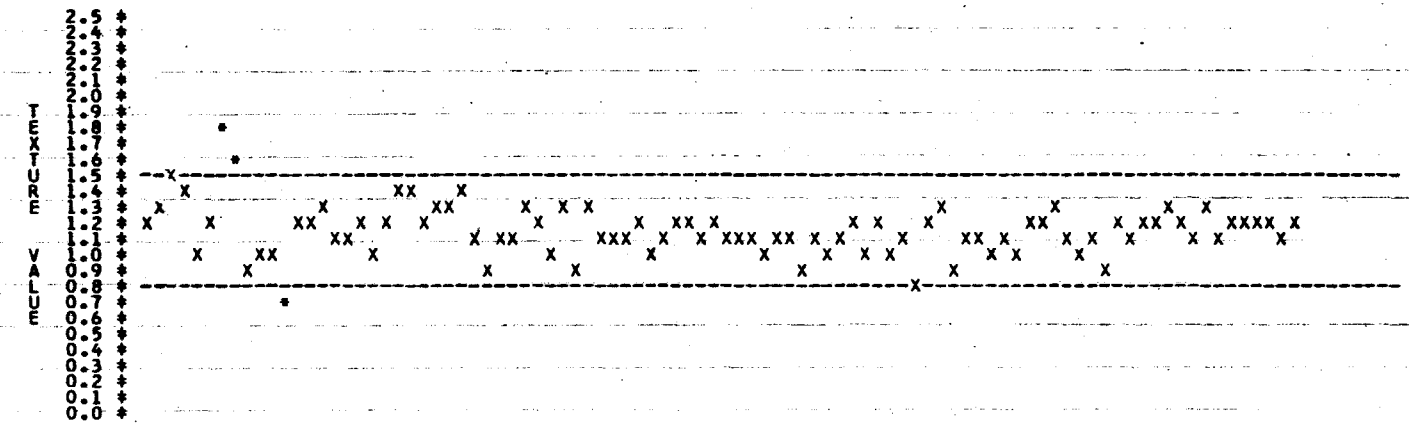
X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES

MAY 61 JUN 61 JUL 61 AUG 61 SEP 61 OCT 61 NOV 61 DEC 61 JAN 62 FEB 62 MAR 62 APR 62 MAY 62 JUN 62 JUL 62

R IS THE RANGE BETWEEN THE HIGHEST AND LOWEST VALUES IN A GROUP OF FOUR SAMPLES



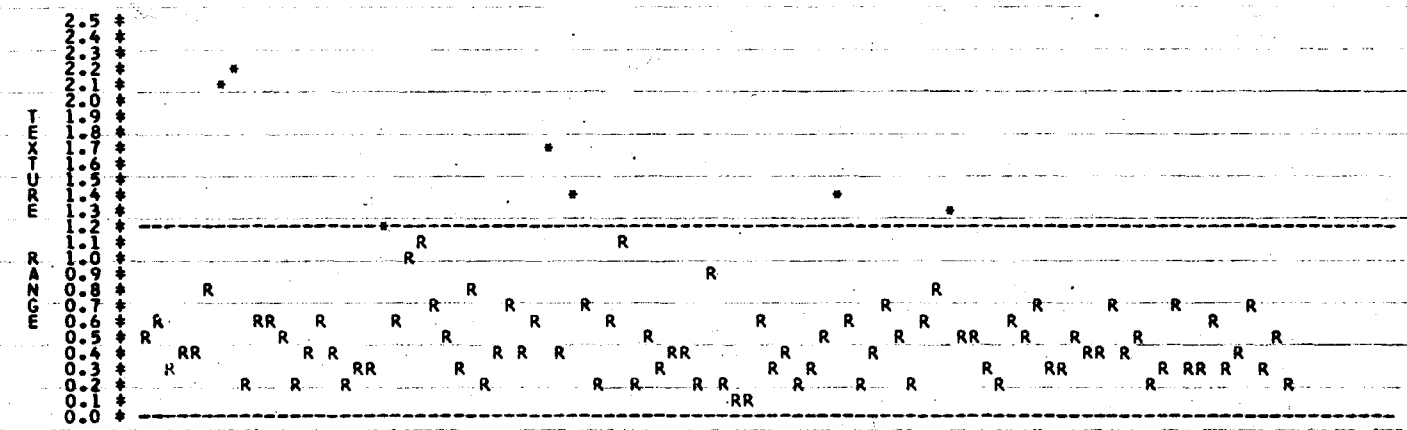
SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A HP ROUTINE PRODUCTION SLUGS
020 CRYSTALLOGRAPHIC PLANE TEXTURE
CIRCUMFERENTIAL DIRECTION SAMPLES



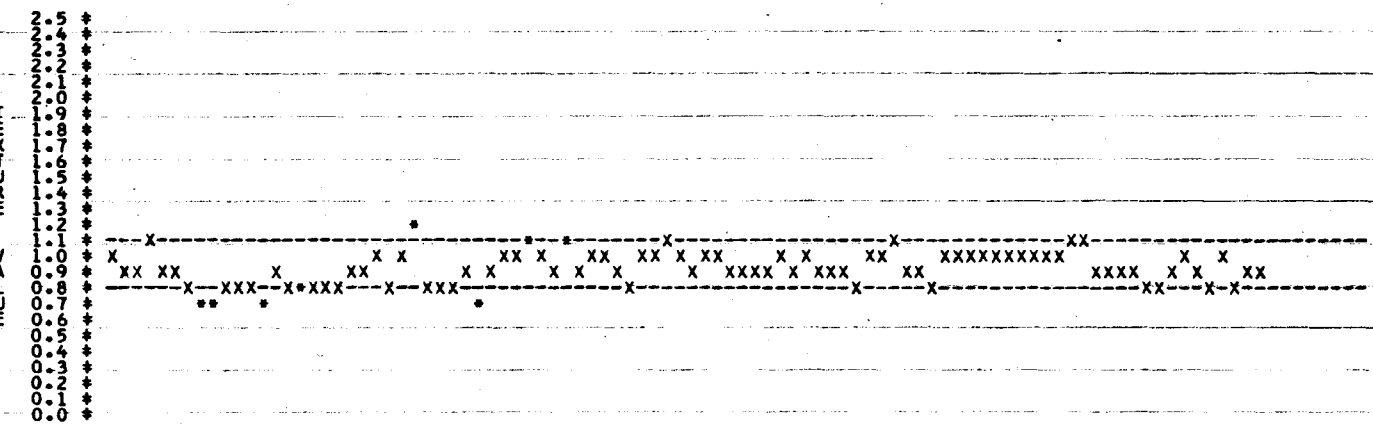
X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES

MAY61 JUN61 JUL61 AUG61 SEP61 OCT61 NOV61 DEC61 JAN62 FEB62 MAR62 APR62 MAY62 JUN62 JUL62

R IS THE RANGE BETWEEN THE HIGHEST AND LOWEST VALUES IN A GROUP OF FOUR SAMPLES



SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A HP ROUTINE PRODUCTION SLUGS
110 CRYSTALLOGRAPHIC PLANE TEXTURE
CIRCUMFERENTIAL DIRECTION SAMPLES



X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES

MAY 61 JUN 61 JUL 61 AUG 61 SEP 61 OCT 61 NOV 61 DEC 61 JAN 62 FEB 62 MAR 62 APR 62 MAY 62 JUN 62 JUL 62

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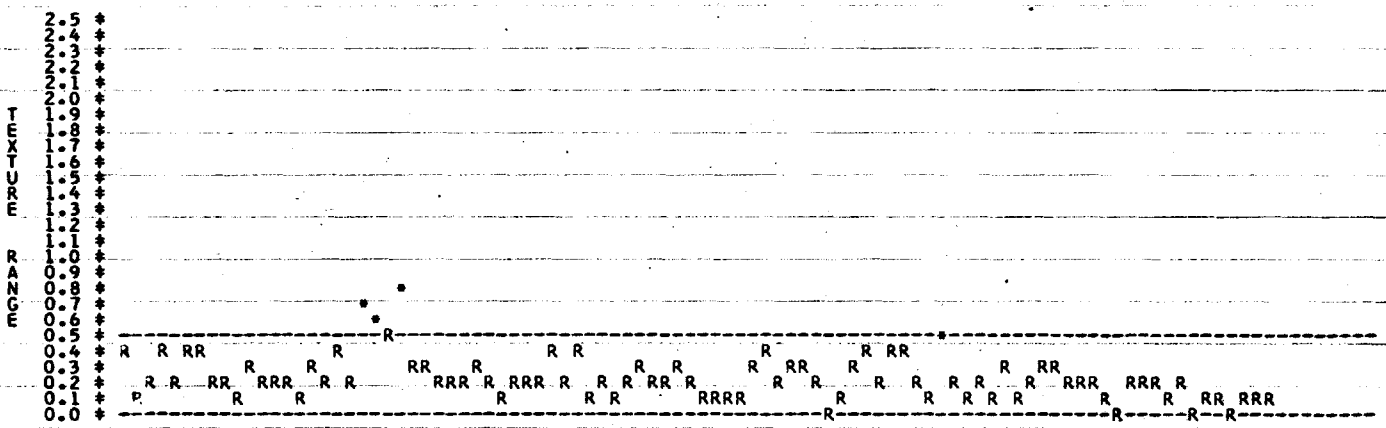
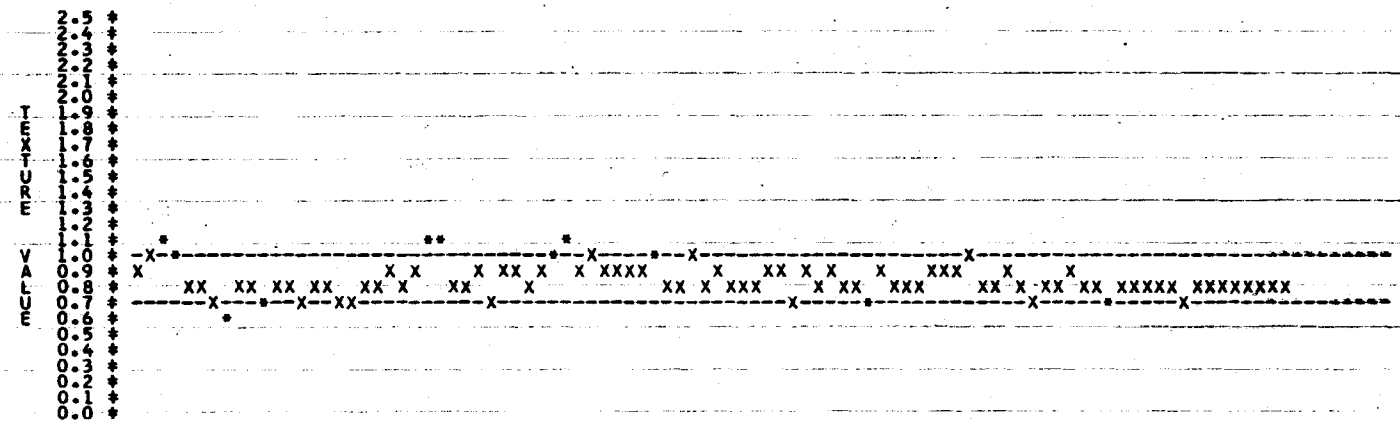


SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A HP ROUTINE PRODUCTION SLUGS
001 CRYSTALLOGRAPHIC PLANE TEXTURE
CIRCUMFERENTIAL-DIRECTION SAMPLES



X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES

MAY61 JUN61 JUL61 AUG61 SEP61 OCT61 NOV61 DEC61 JAN62 FEB62 MAR62 APR62 MAY62 JUN62 JUL62

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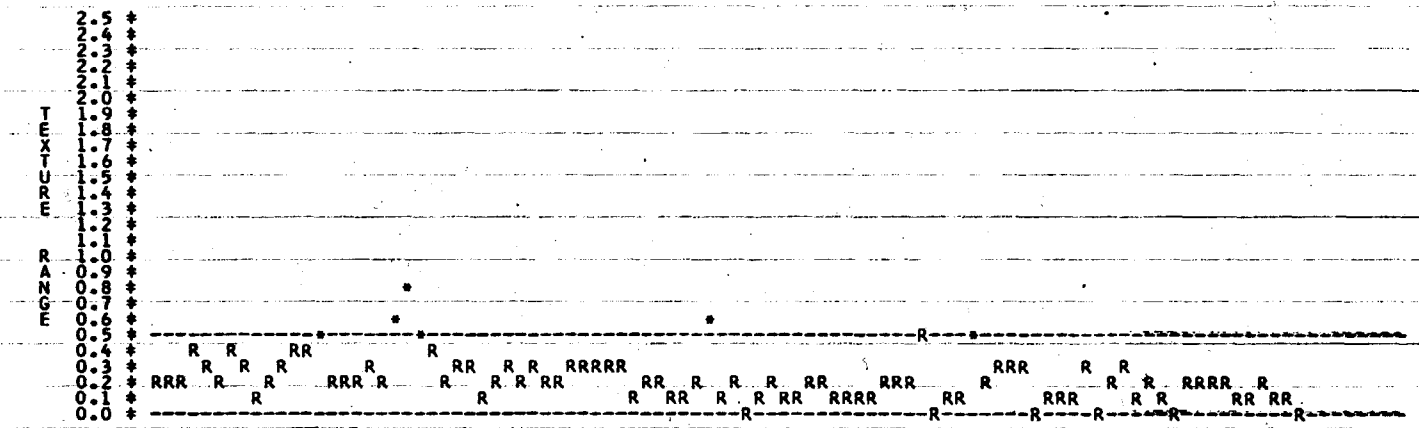
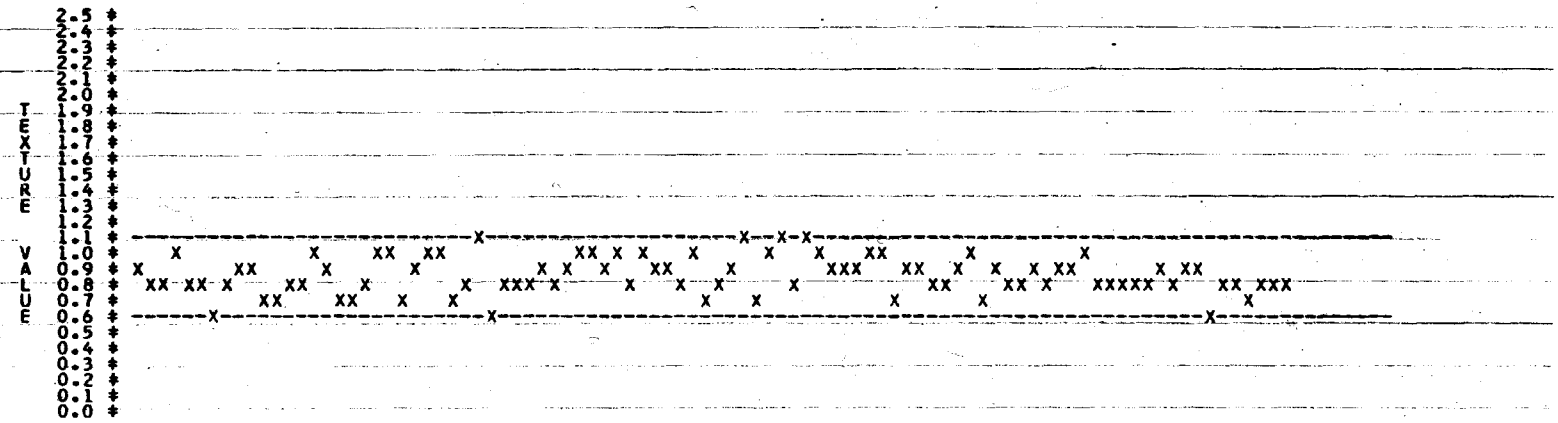
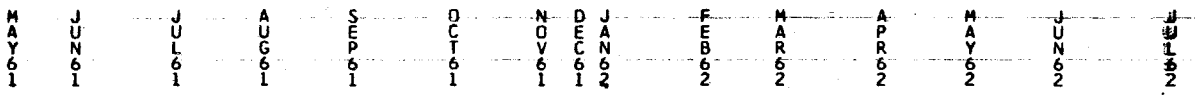


SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A HP ROUTINE PRODUCTION SLUGS
002 CRYSTALLOGRAPHIC PLANE TEXTURE
CIRCUMFERENTIAL DIRECTION SAMPLES



X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES



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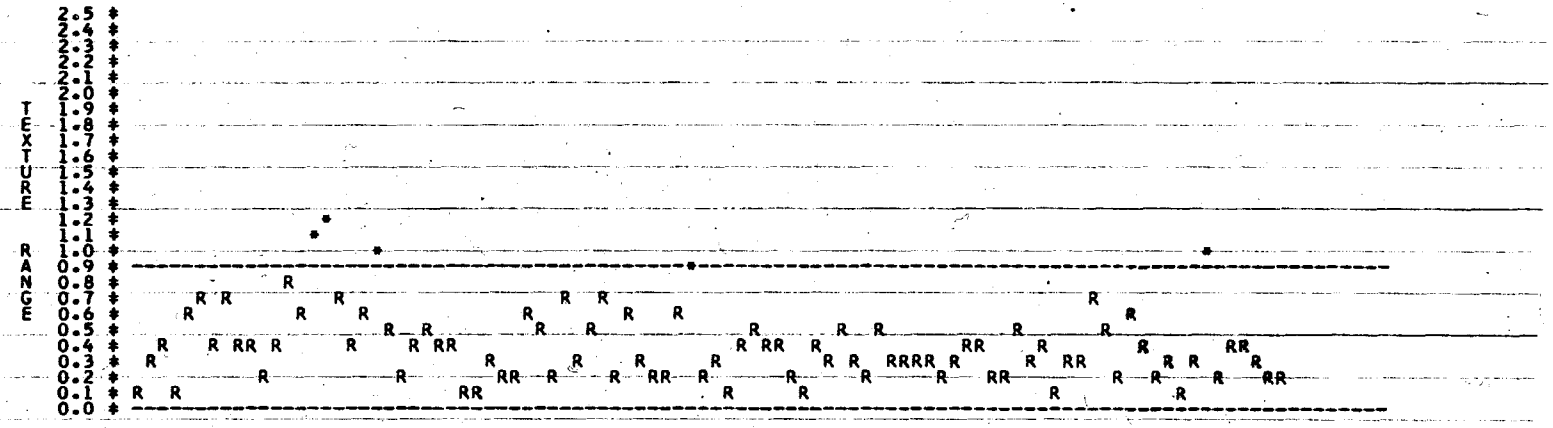
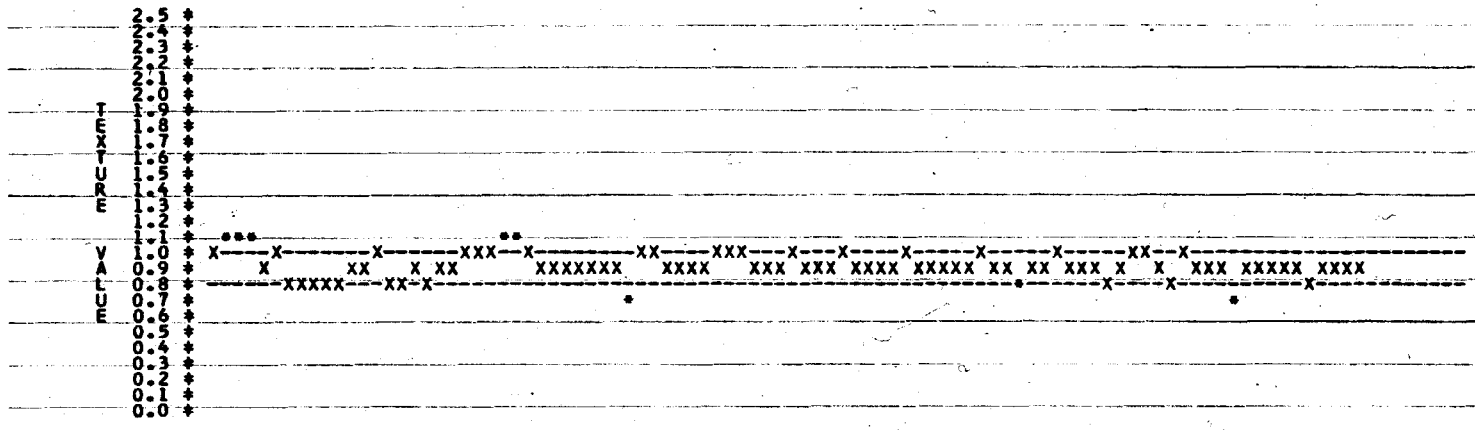


SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A HP ROUTINE PRODUCTION SLUGS
111 CRYSTALLOGRAPHIC PLANE TEXTURE
CIRCUMFERENTIAL DIRECTION SAMPLES



X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES

MAY 61 JUN 61 JUL 61 AUG 61 SEP 61 OCT 61 NOV 61 DEC 61 JAN 62 FEB 62 MAR 62 APR 62 MAY 62 JUN 62 JUL 62

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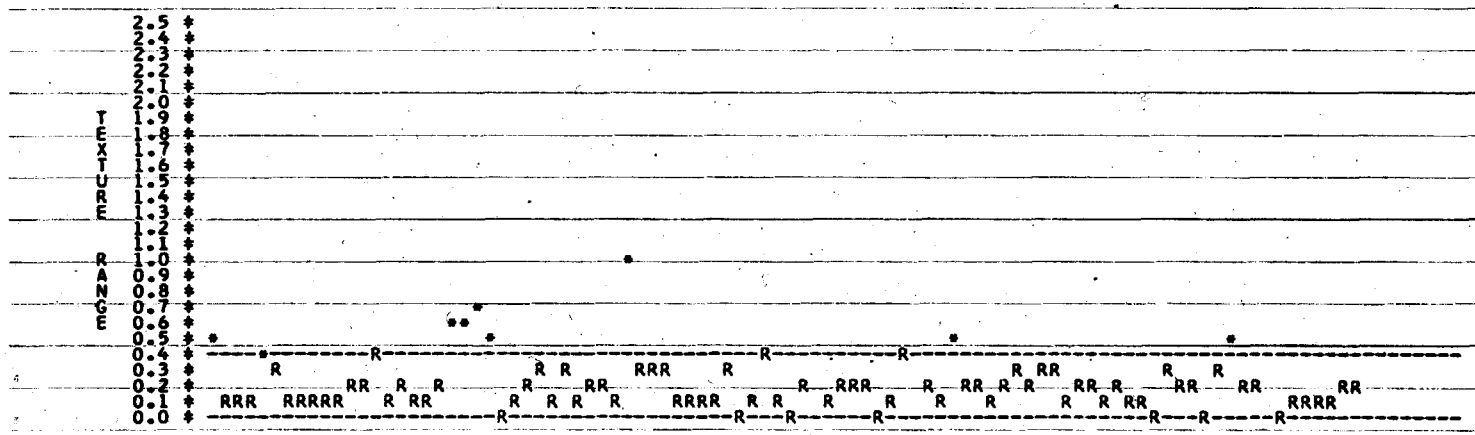
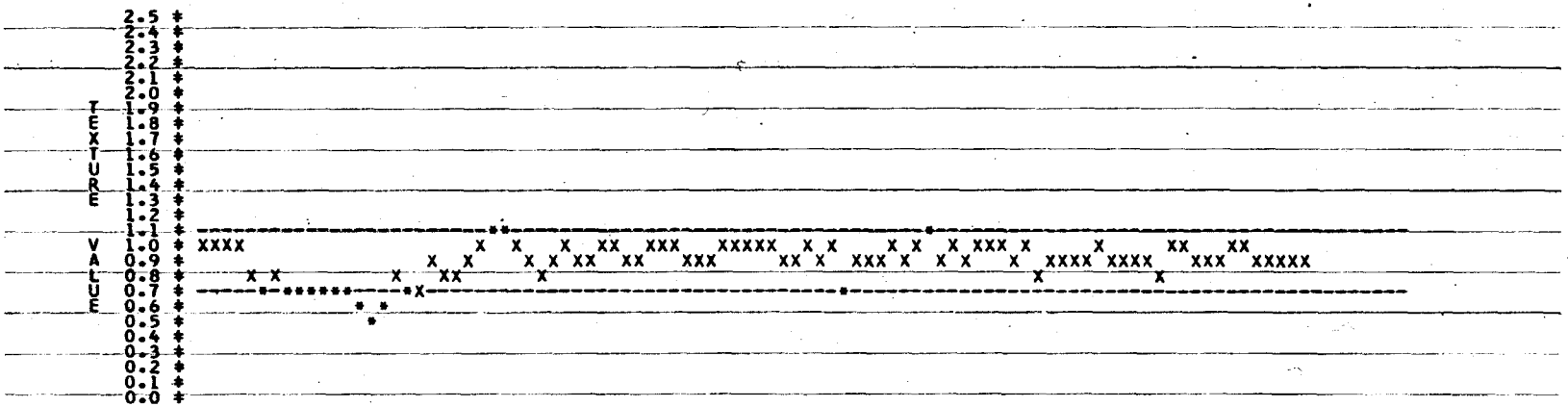


SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A HP ROUTINE PRODUCTION SLUGS
112 CRYSTALLOGRAPHIC PLANE TEXTURE
CIRCUMFERENTIAL DIRECTION SAMPLES



X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES

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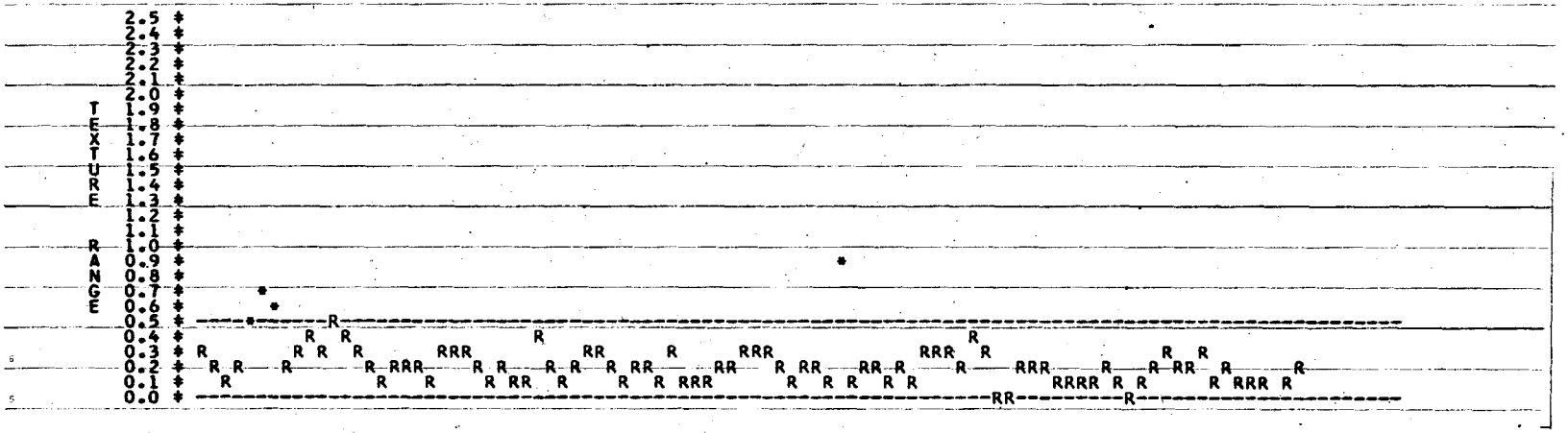
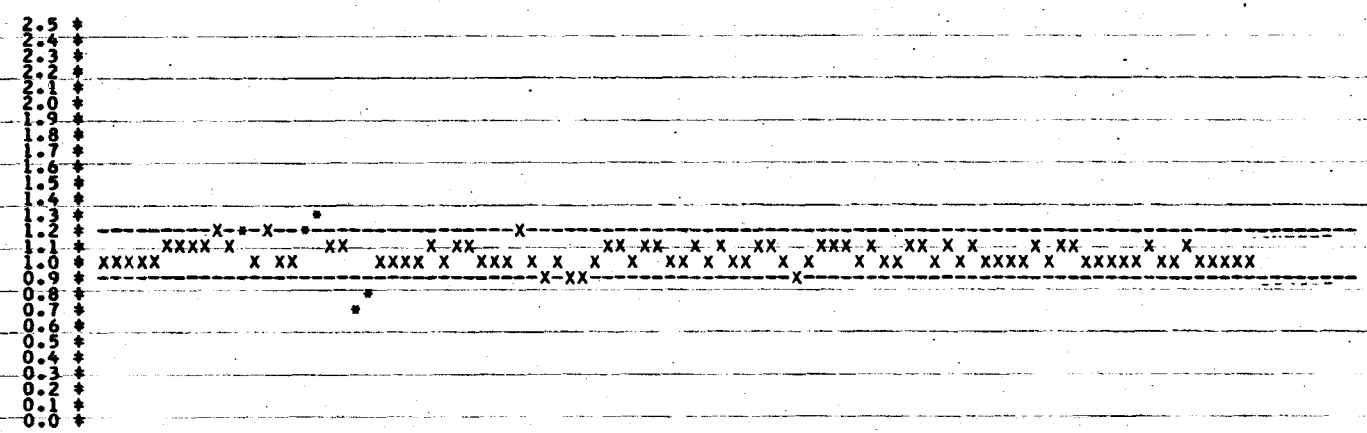


SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A HP ROUTINE PRODUCTION SLUGS
131 CRYSTALLOGRAPHIC PLANE TEXTURE
CIRCUMFERENTIAL DIRECTION SAMPLES



X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES

MAY 61 JUN 61 JUL 61 AUG 61 SEP 61 OCT 61 NOV 61 DEC 61 JAN 62 FEB 62 MAR 62 APR 62 MAY 62 JUN 62 JUL 62

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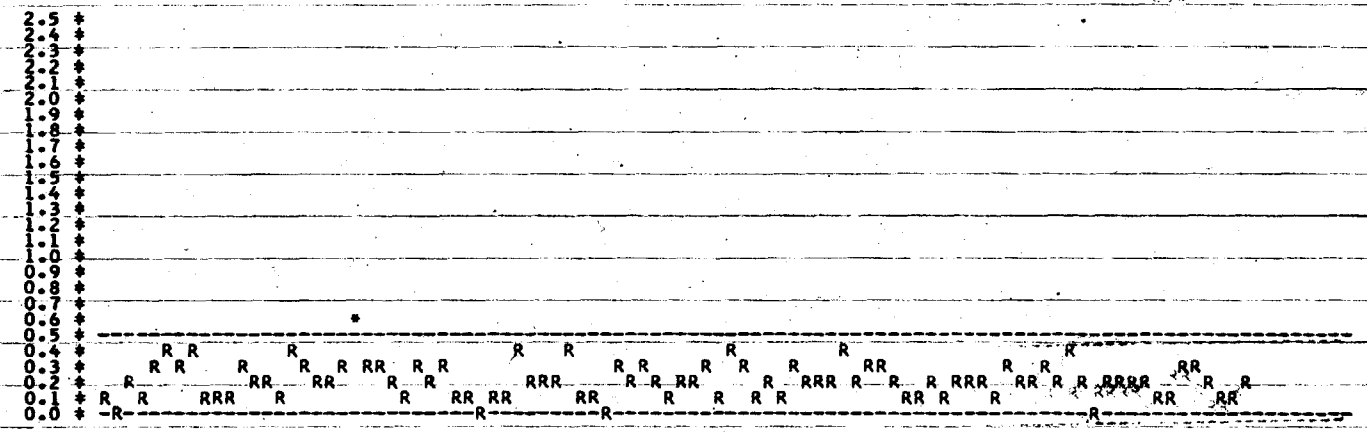
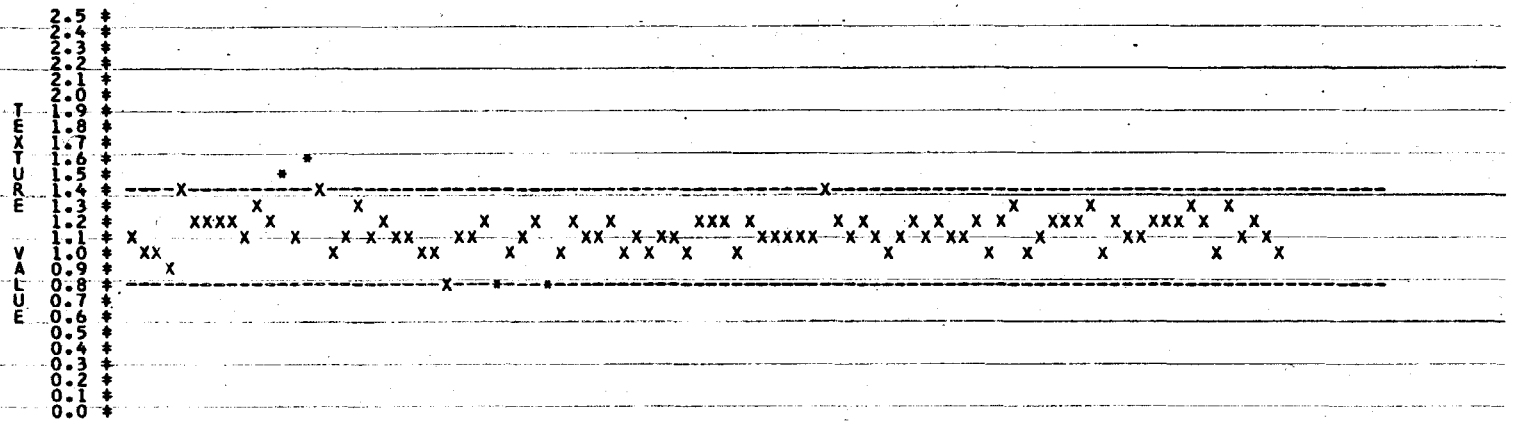


SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A HP ROUTINE PRODUCTION SLUGS
023 CRYSTALLOGRAPHIC PLANE TEXTURE
CIRCUMFERENTIAL DIRECTION SAMPLES



X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES

MAY61 JUN61 JUL61 AUG61 SEP61 OCT61 NOV61 DEC61 JAN62 FEB62 MAR62 APR62 MAY62 JUN62 JUL62

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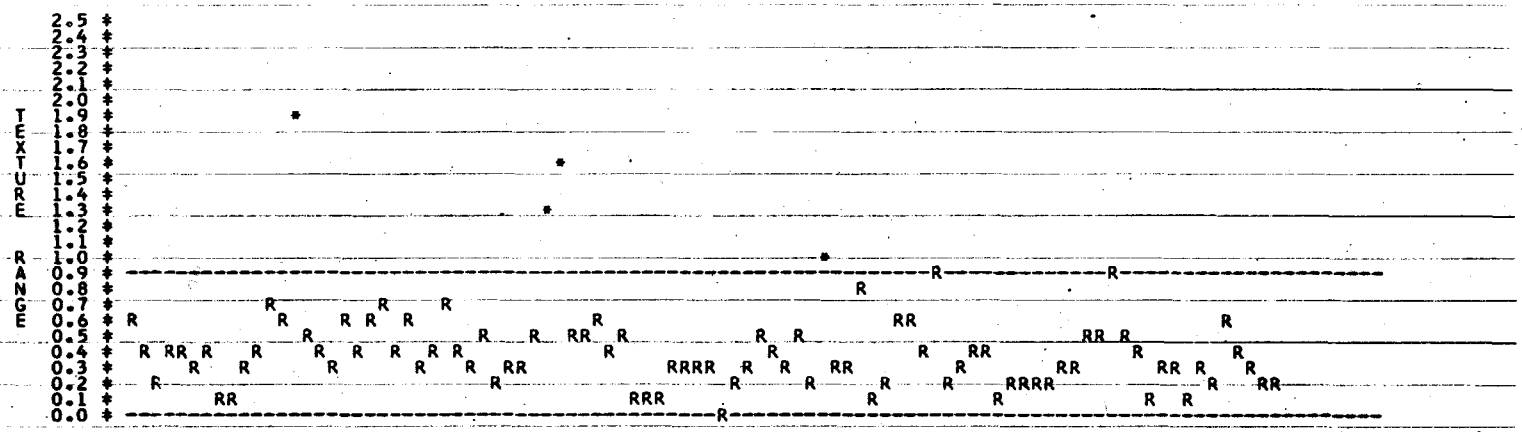
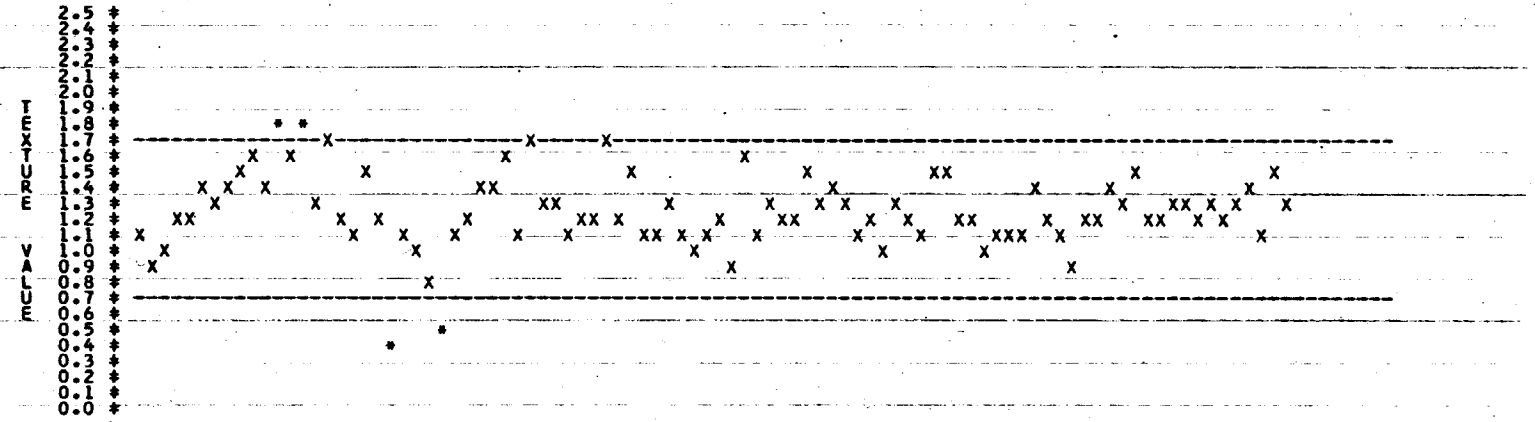
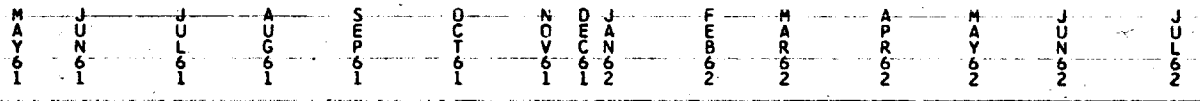


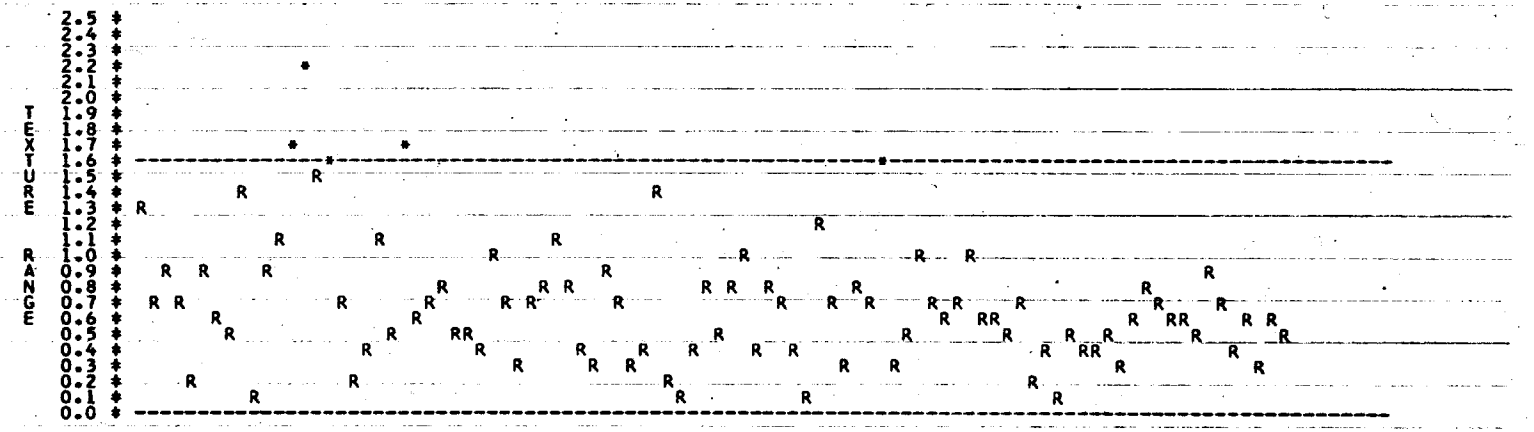
SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A HP ROUTINE PRODUCTION SLUGS
200 CRYSTALLOGRAPHIC PLANE TEXTURE
CIRCUMFERENTIAL DIRECTION SAMPLES



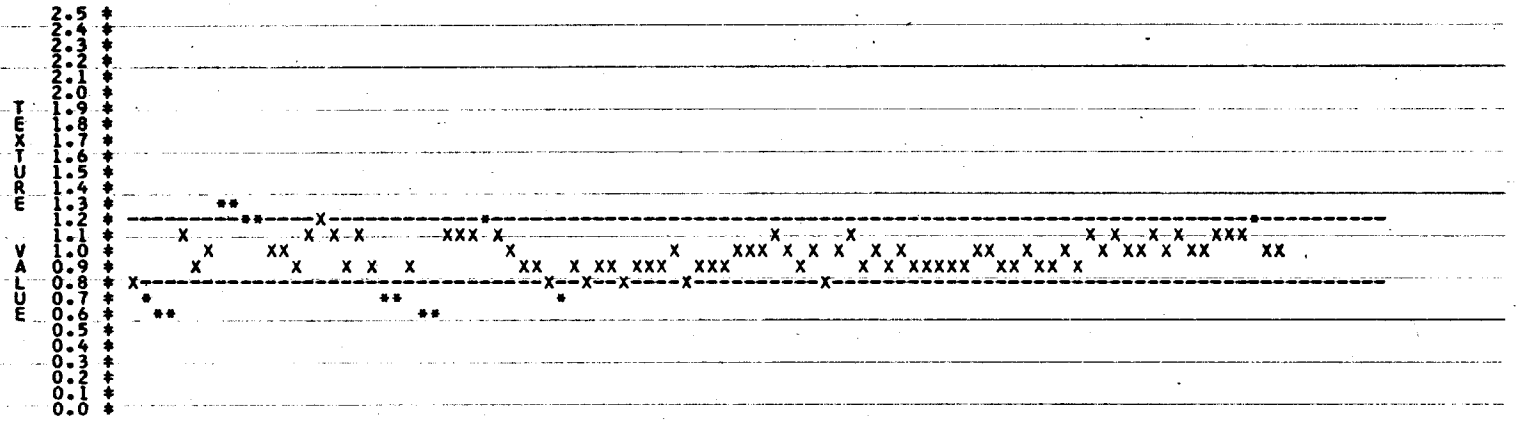
X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES



R IS THE RANGE BETWEEN THE HIGHEST AND LOWEST VALUES IN A GROUP OF FOUR SAMPLES



SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A HP ROUTINE PRODUCTION SLUGS
113 CRYSTALLOGRAPHIC PLANE TEXTURE
CIRCUMFERENTIAL DIRECTION SAMPLES



X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES

MAY 61 JUN 61 JUL 61 AUG 61 SEP 61 OCT 61 NOV 61 DEC 61 JAN 62 FEB 62 MAR 62 APR 62 MAY 62 JUN 62 JUL 62

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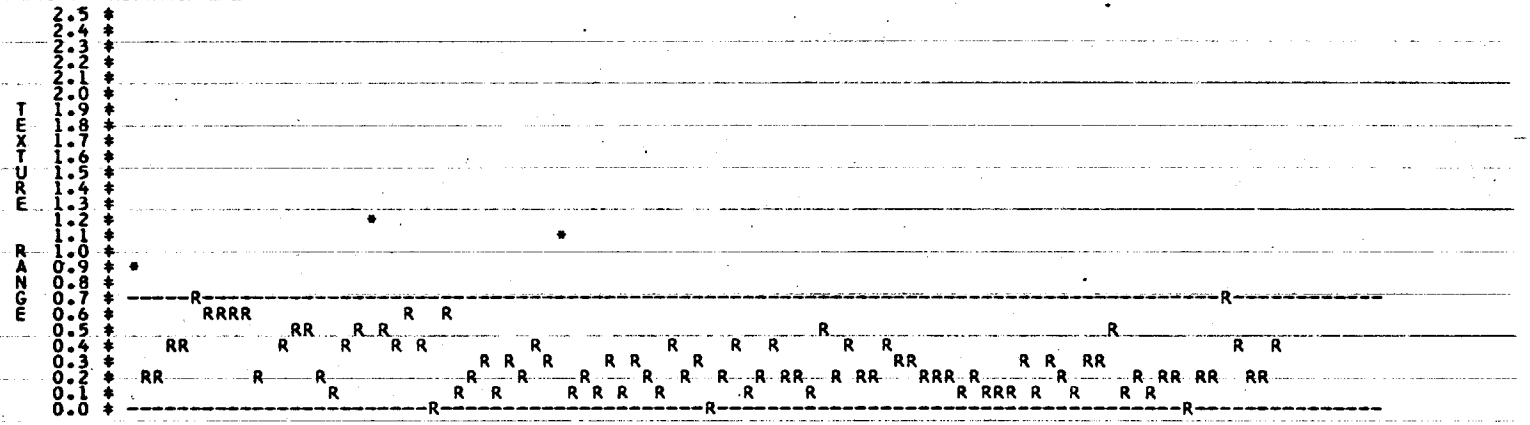
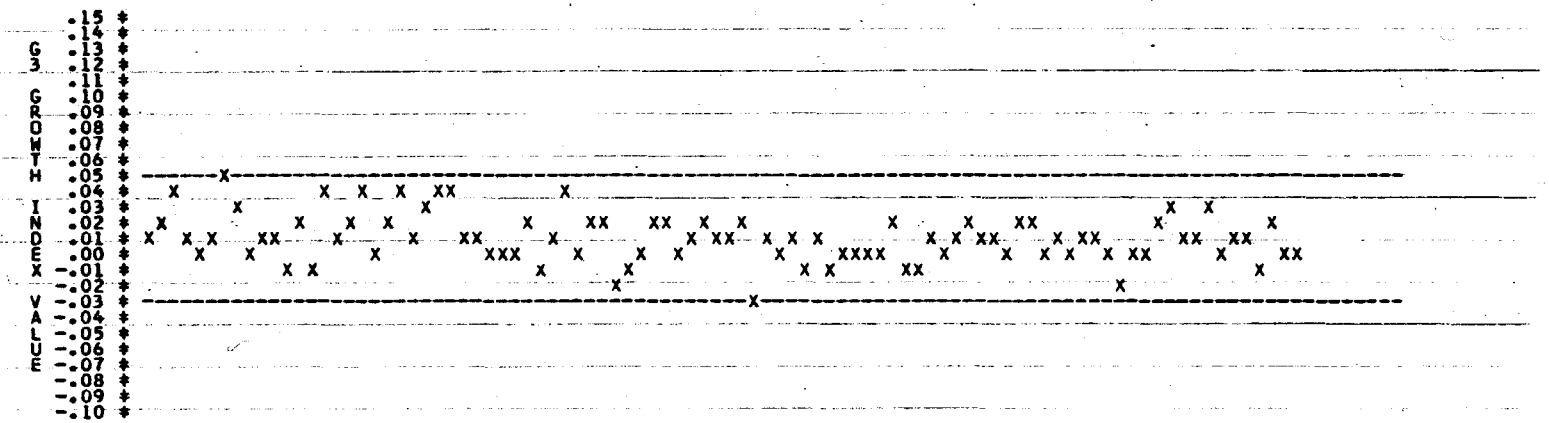


SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A HP ROUTINE PRODUCTION SLUGS
G3 AREA WEIGHT GROWTH INDEX
CIRCUMFERENTIAL DIRECTION SAMPLES



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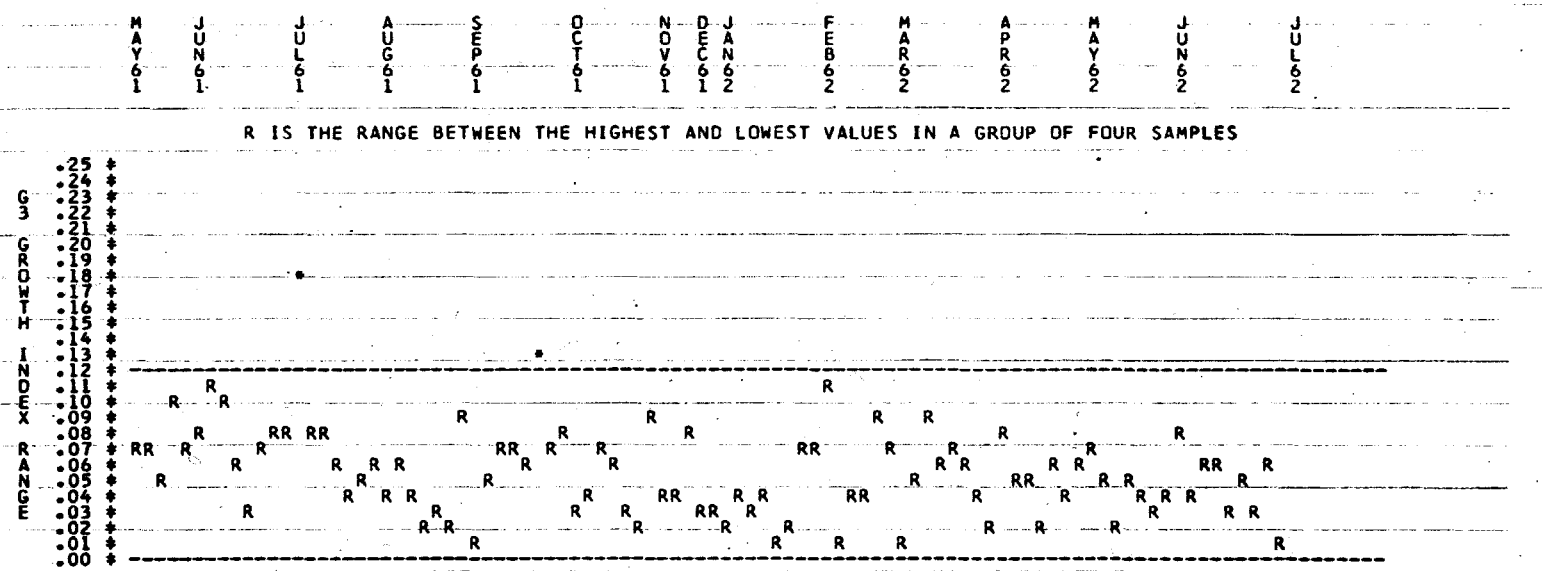
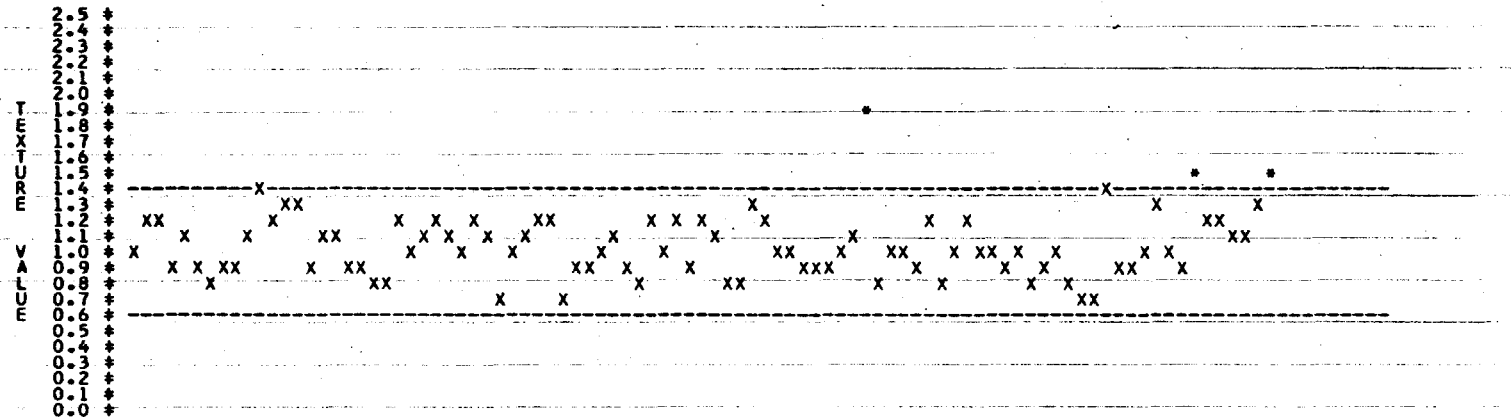


MAY 61 JUN 61 JUL 61 AUG 61 SEP 61 OCT 61 NOV 61 DEC 61 JAN 62 FEB 62 MAR 62 APR 62 MAY 62 JUN 62 JUL 62

R IS THE RANGE BETWEEN THE HIGHEST AND LOWEST VALUES IN A GROUP OF FOUR SAMPLES

SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A SCNC ROUTINE PRODUCTION SLUGS
020 CRYSTALLOGRAPHIC PLANE TEXTURE
LONGITUDINAL DIRECTION SAMPLES



X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES

APR 61 MAY 61 JUN 61 JUL 61 AUG 61 SEP 61 OCT 61 NOV 61 DEC 61 JAN 62 FEB 62 MAR 62 APR 62 MAY 62 JUN 62 JUL 62

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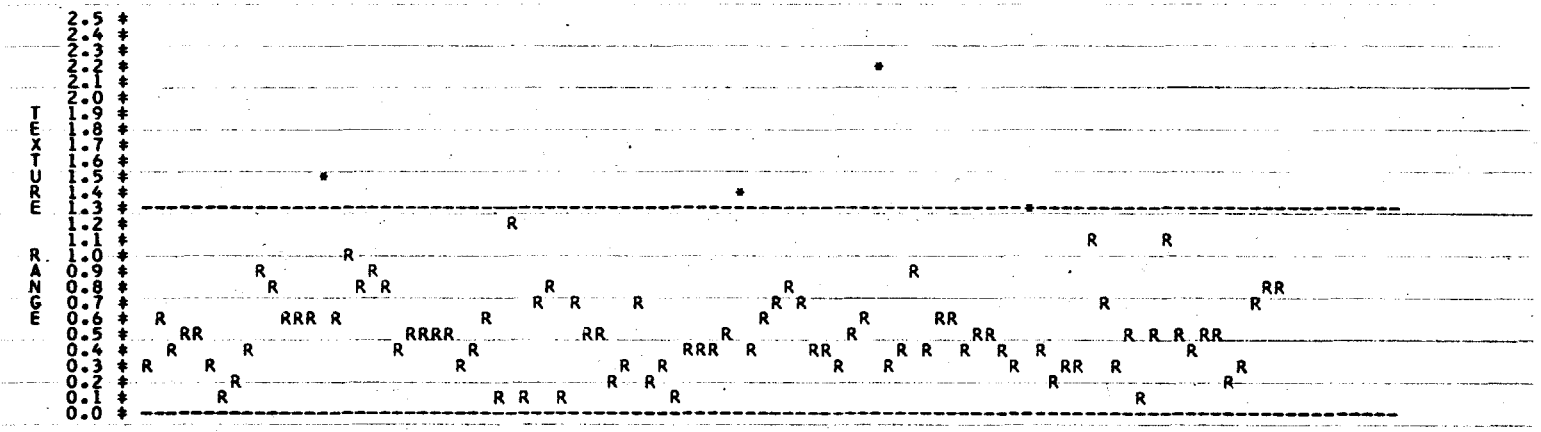
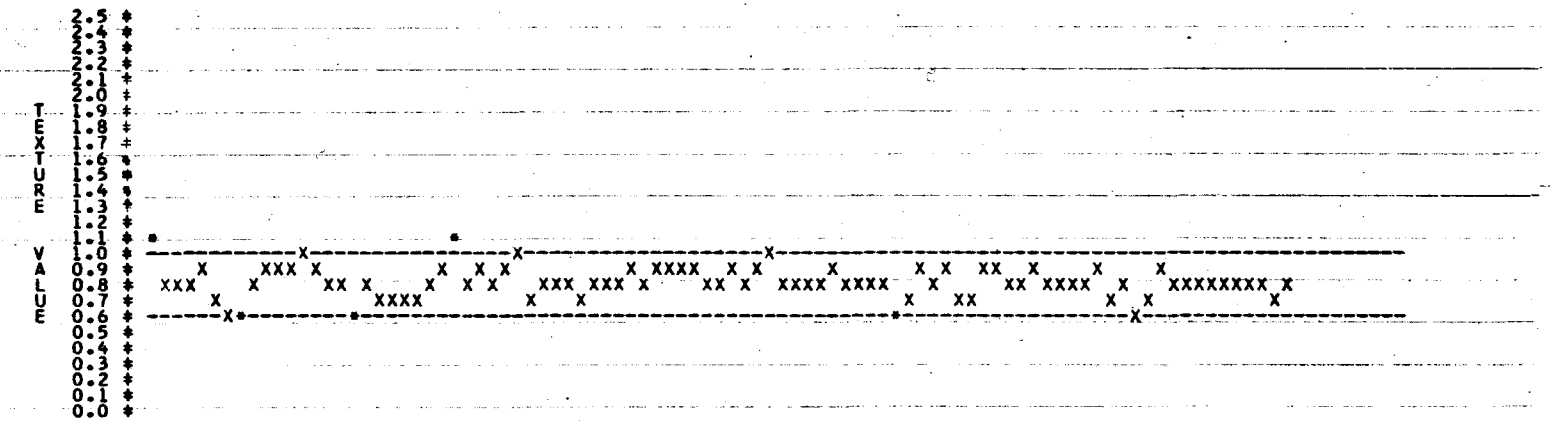


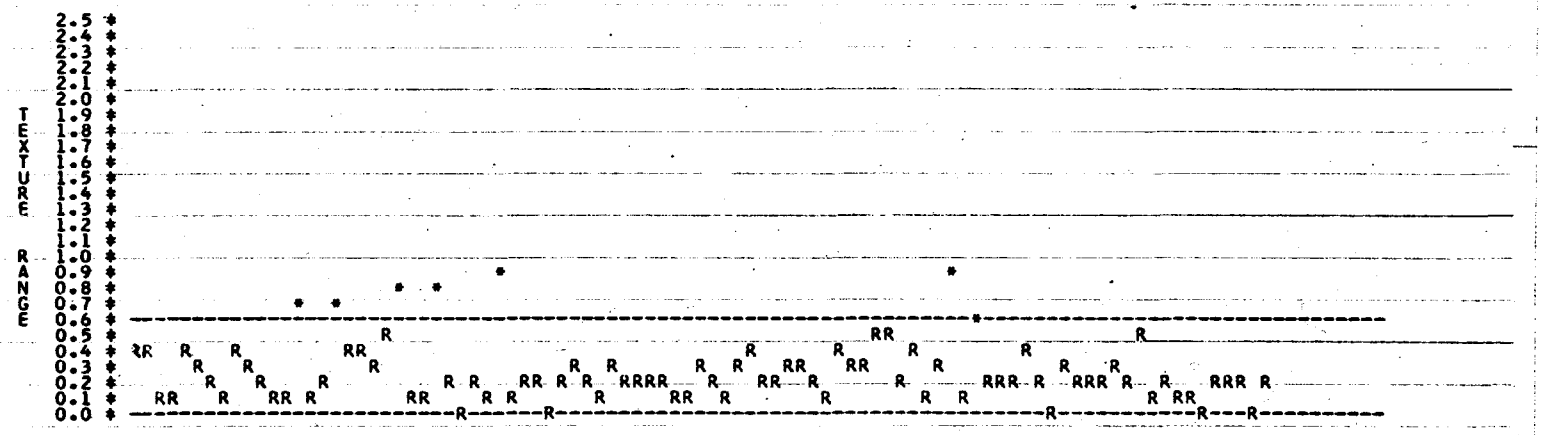
SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A SCNC ROUTINE PRODUCTION SLUGS
110 CRYSTALLOGRAPHIC PLANE TEXTURE
LONGITUDINAL DIRECTION SAMPLES



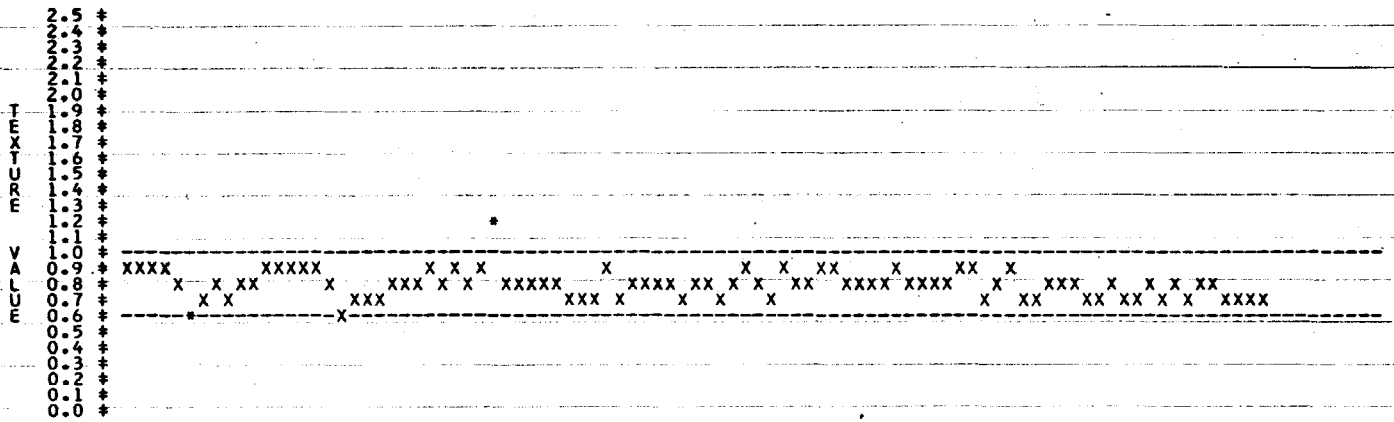
X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES

APR 61	MAY 61	JUN 61	JUL 61	AUG 61	SEP 61	OCT 61	NOV 61	DEC 61	JAN 62	FEB 62	MAR 62	APR 62	MAY 62	JUN 62	JUL 62

R IS THE RANGE BETWEEN THE HIGHEST AND LOWEST VALUES IN A GROUP OF FOUR SAMPLES



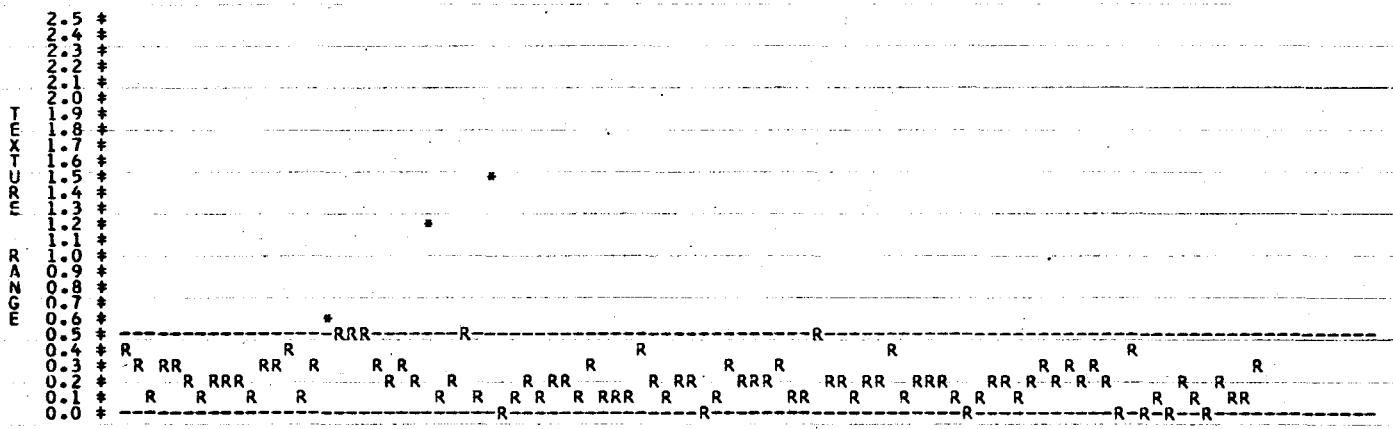
SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A SCNC ROUTINE PRODUCTION SLUGS
021 CRYSTALLOGRAPHIC PLANE TEXTURE
LONGITUDINAL DIRECTION SAMPLES



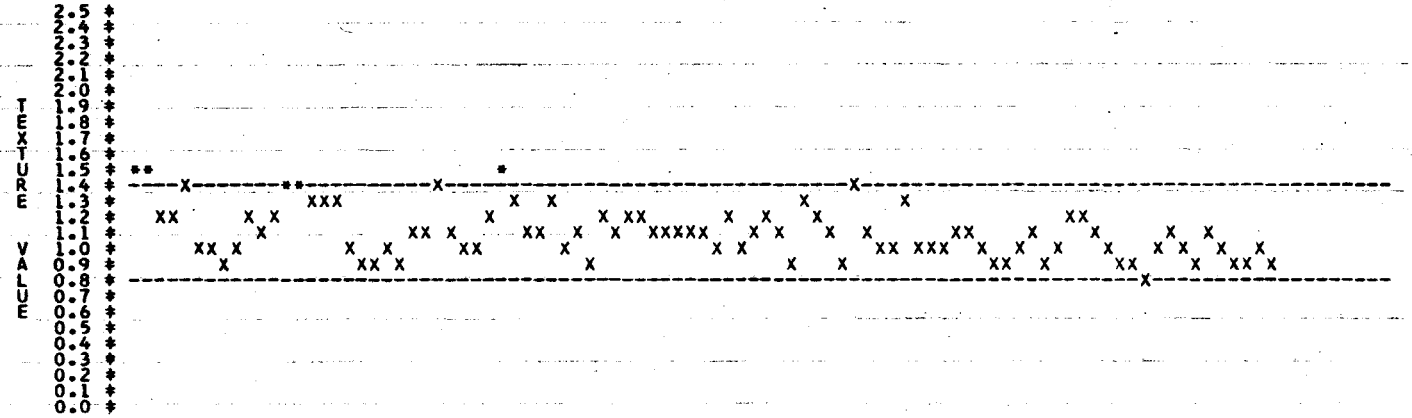
X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES

APR 61 · MAY 61 · JUN 61 · JUL 61 · AUG 61 · SEP 61 · OCT 61 · NOV 61 · DEC 61 · JAN 62 · FEB 62 · MAR 62 · APR 62 · MAY 62 · JUN 62 · JUL 62

R IS THE RANGE BETWEEN THE HIGHEST AND LOWEST VALUES IN A GROUP OF FOUR SAMPLES



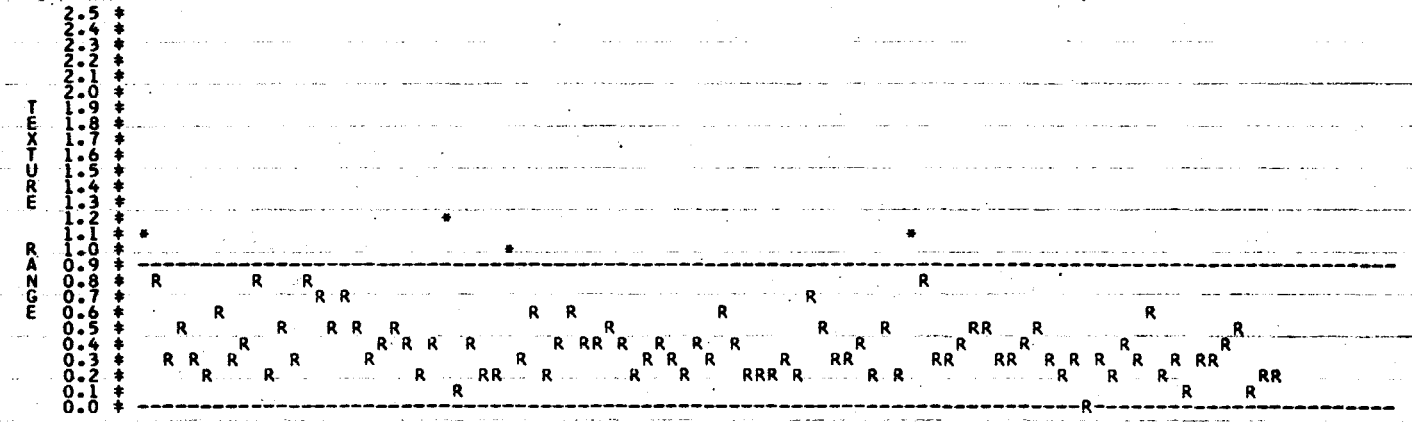
SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A SCNC ROUTINE PRODUCTION SLUGS
002 CRYSTALLOGRAPHIC PLANE TEXTURE
LONGITUDINAL DIRECTION SAMPLES



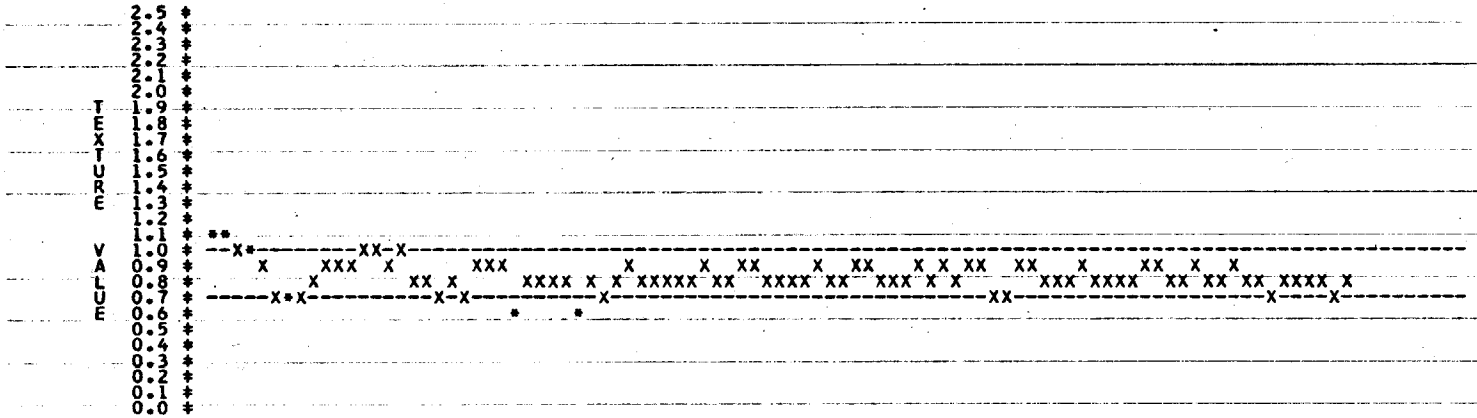
X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES

APR 61 | MAY 61 | JUN 61 | JUL 61 | AUG 61 | SEP 61 | OCT 61 | NOV 61 | DEC 61 | JAN 62 | FEB 62 | MAR 62 | APR 62 | MAY 62 | JUN 62 | JUL 62

R IS THE RANGE BETWEEN THE HIGHEST AND LOWEST VALUES IN A GROUP OF FOUR SAMPLES



SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A SCNC ROUTINE PRODUCTION SLUGS
111 CRYSTALLOGRAPHIC PLANE TEXTURE
LONGITUDINAL DIRECTION SAMPLES



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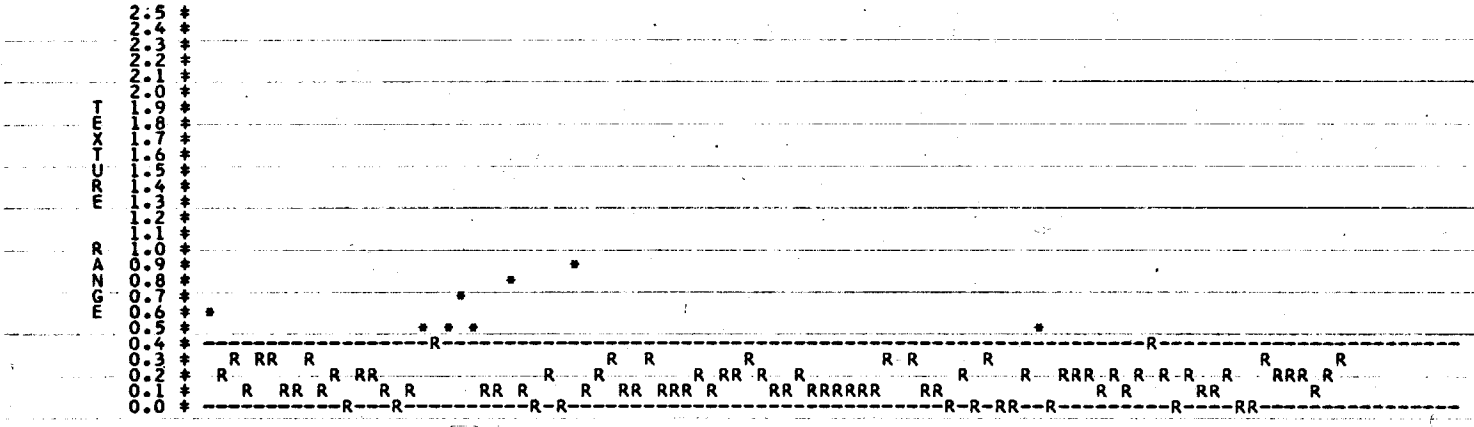
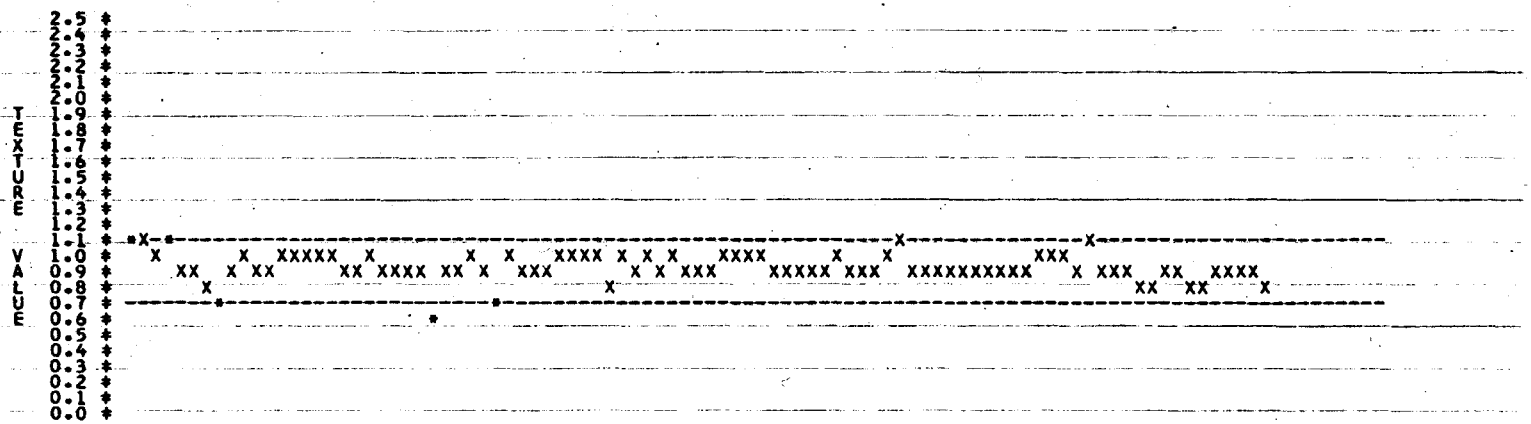
APR 61 · MAY 61 · JUN 61 · JUL 61 · AUG 61 · SEP 61 · OCT 61 · NOV 61 · DEC 61 · JAN 62 · FEB 62 · MAR 62 · APR 62 · MAY 62 · JUN 62 · JUL 62

R IS THE RANGE BETWEEN THE HIGHEST AND LOWEST VALUES IN A GROUP OF FOUR SAMPLES



SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A SCNC ROUTINE PRODUCTION SLUGS
112 CRYSTALLOGRAPHIC PLANE TEXTURE
LONGITUDINAL DIRECTION SAMPLES



X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES

APR 61 MAY 61 JUN 61 JUL 61 AUG 61 SEP 61 OCT 61 NOV 61 DEC 61 JAN 62 FEB 62 MAR 62 APR 62 MAY 62 JUN 62 JUL 62

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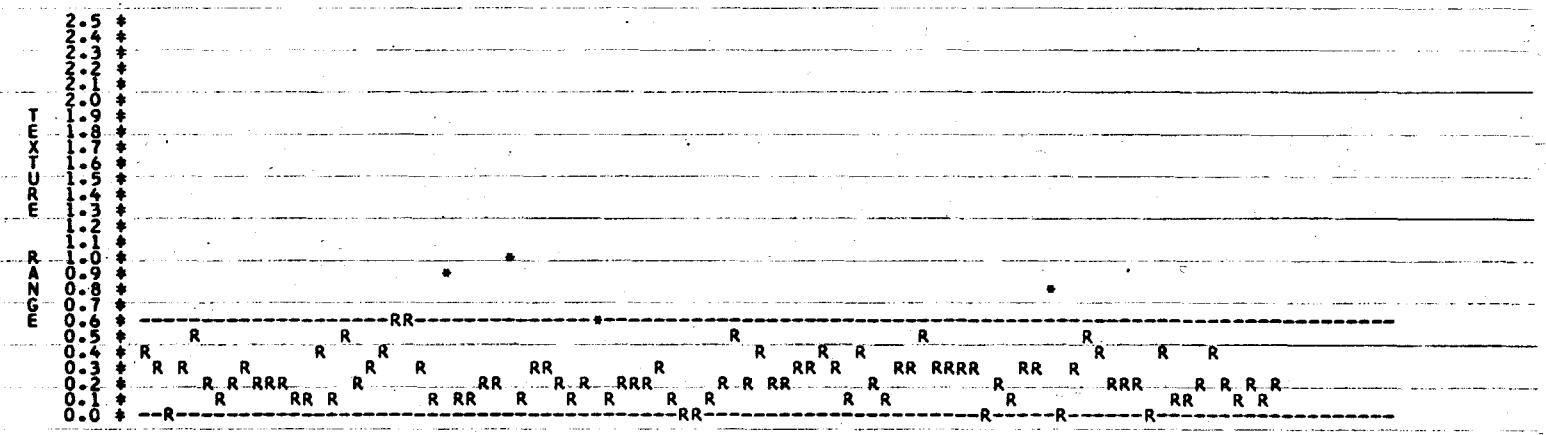
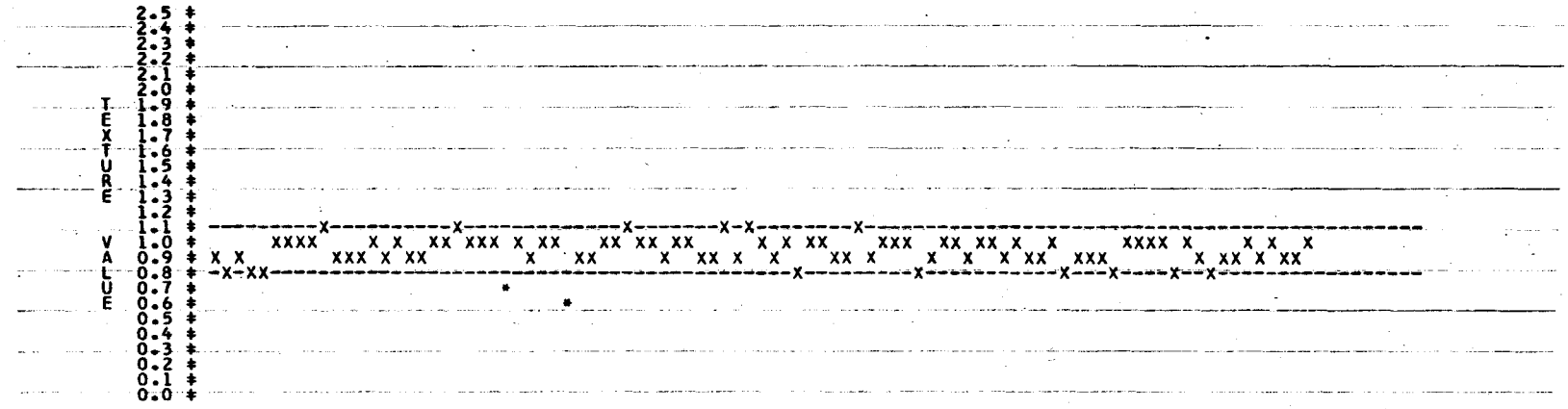


SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A SCNC ROUTINE PRODUCTION SLUGS
131 CRYSTALLOGRAPHIC PLANE TEXTURE
LONGITUDINAL DIRECTION SAMPLES



X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES

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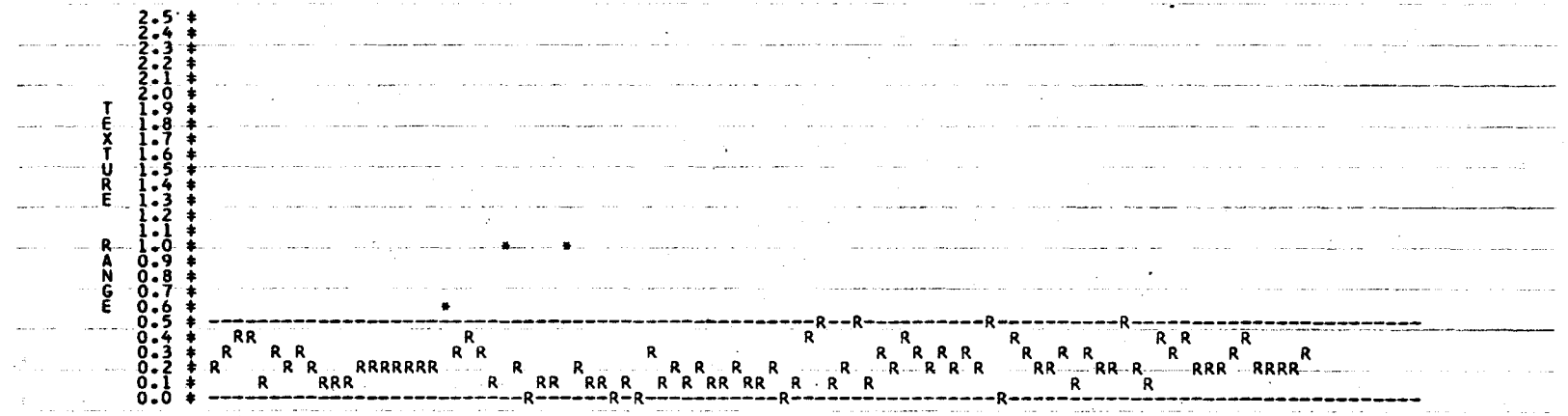
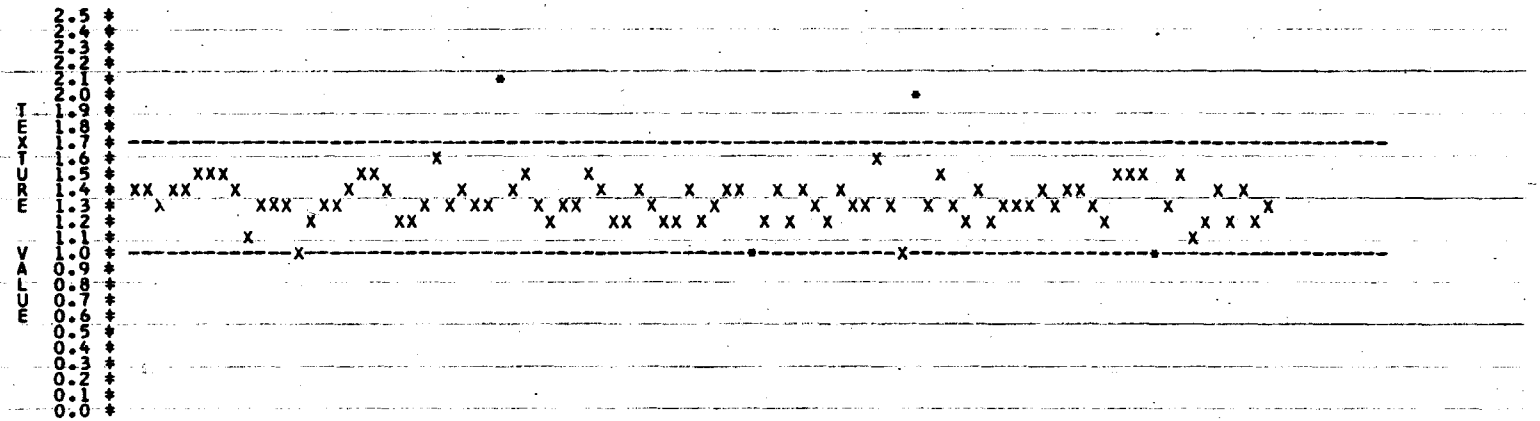


SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A SCNC ROUTINE PRODUCTION SLUGS
023 CRYSTALLOGRAPHIC PLANE TEXTURE
LONGITUDINAL DIRECTION SAMPLES



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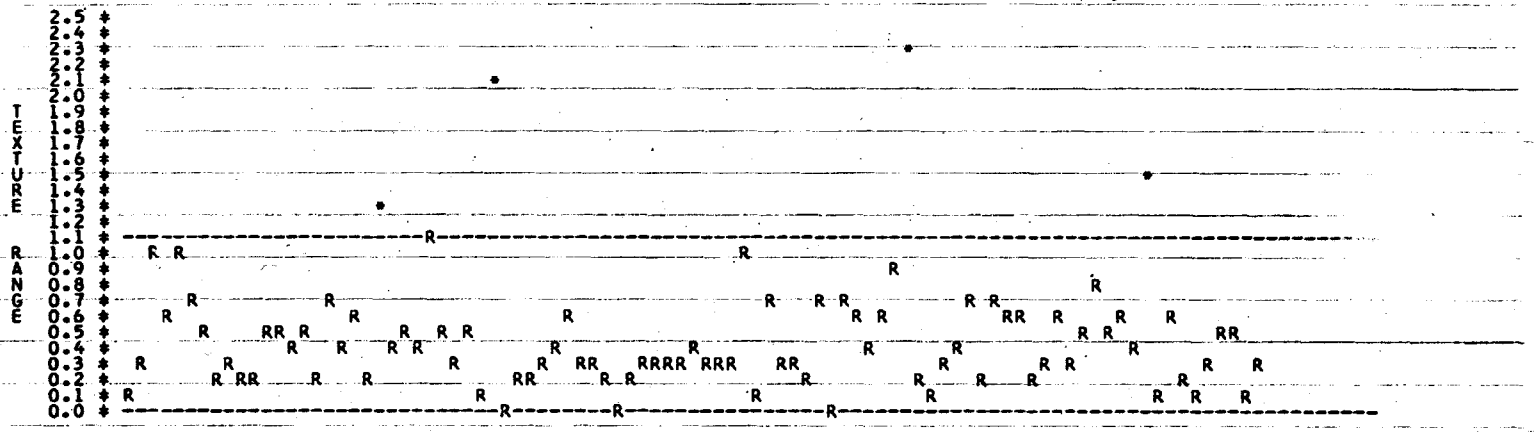
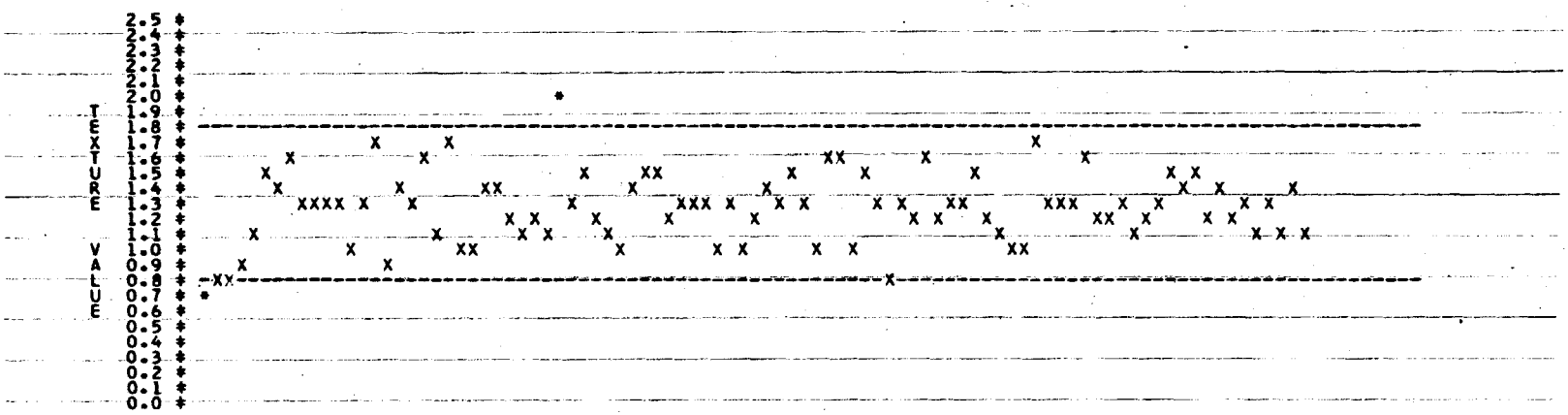


SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A SCNC ROUTINE PRODUCTION SLUGS
200 CRYSTALLOGRAPHIC PLANE TEXTURE
LONGITUDINAL DIRECTION SAMPLES



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APR 61 | MAY 61 | JUN 61 | JUL 61 | AUG 61 | SEP 61 | OCT 61 | NOV 61 | DEC 61 | JAN 62 | FEB 62 | MAR 62 | APR 62 | MAY 62 | JUN 62 | JUL 62

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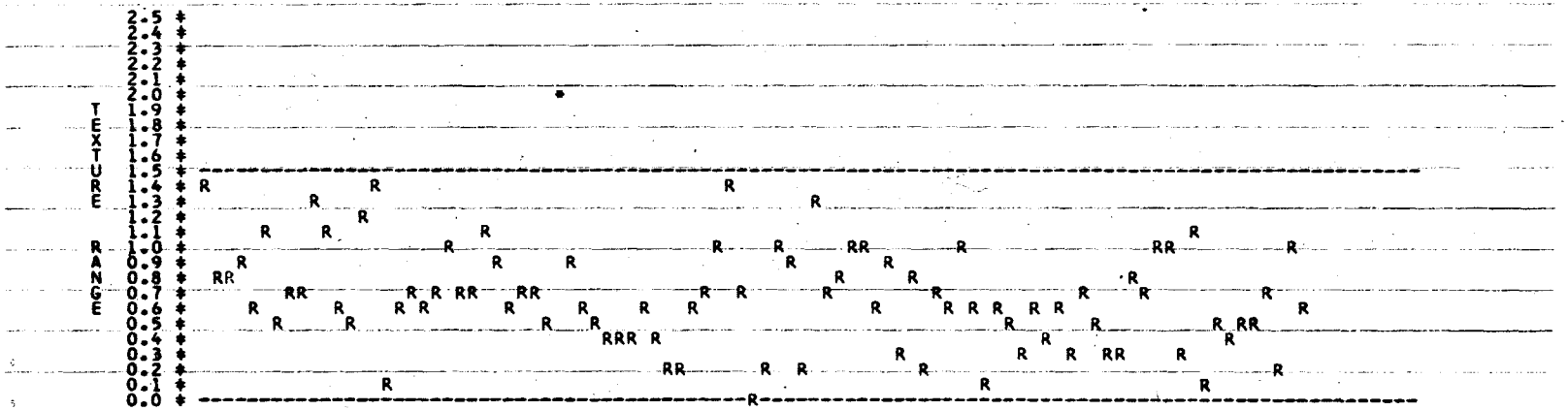
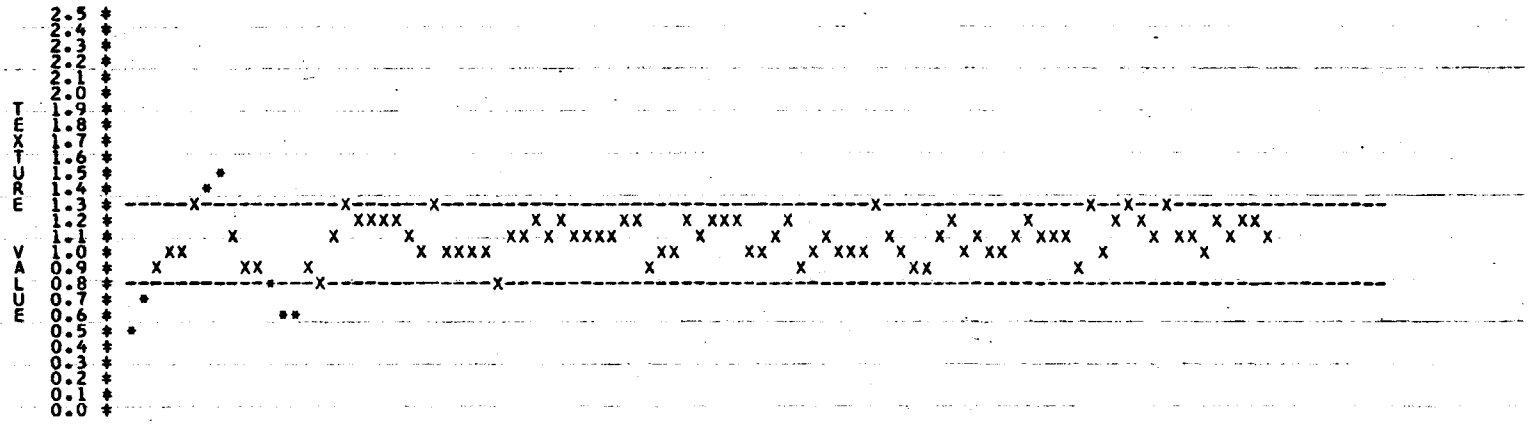


SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A SCNC ROUTINE PRODUCTION SLUGS
113 CRYSTALLOGRAPHIC PLANE TEXTURE
LONGITUDINAL DIRECTION SAMPLES



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APR 61	MAY 61	JUN 61	JUL 61	AUG 61	SEP 61	OCT 61	NOV 61	DEC 61	JAN 62	FEB 62	MAR 62	APR 62	MAY 62	JUN 62	JUL 62

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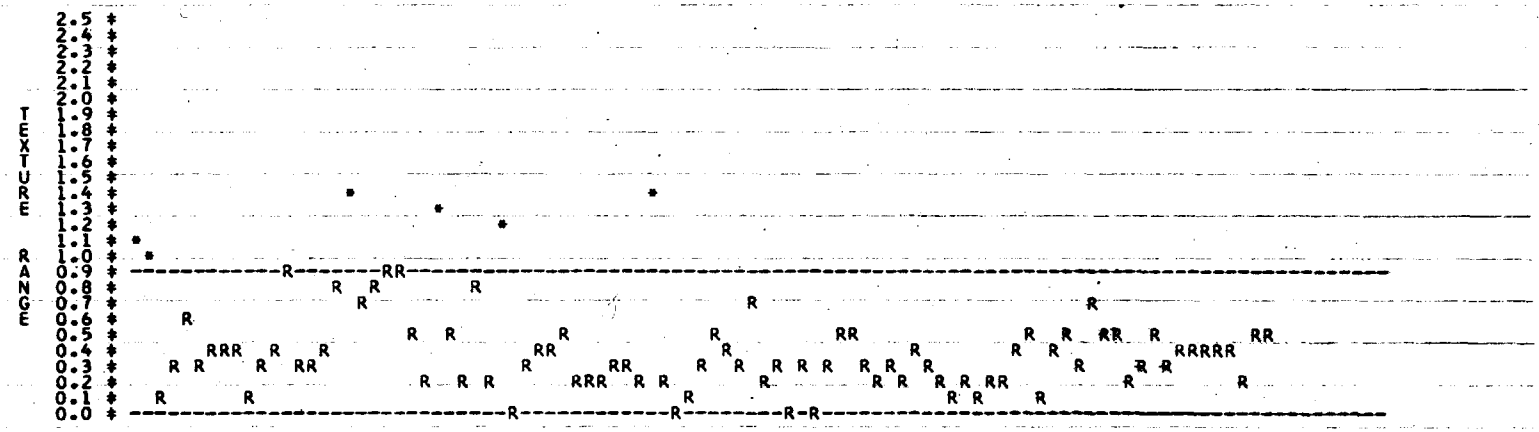
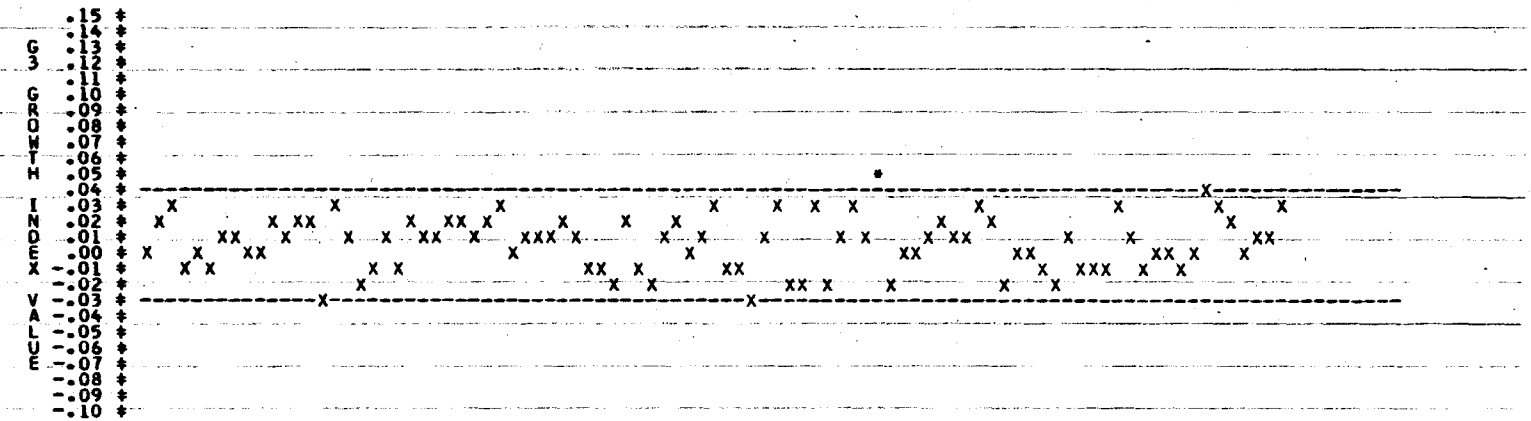


SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A SCNC ROUTINE PRODUCTION SLUGS
G3 AREA WEIGHT GROWTH INDEX
LONGITUDINAL DIRECTION SAMPLES



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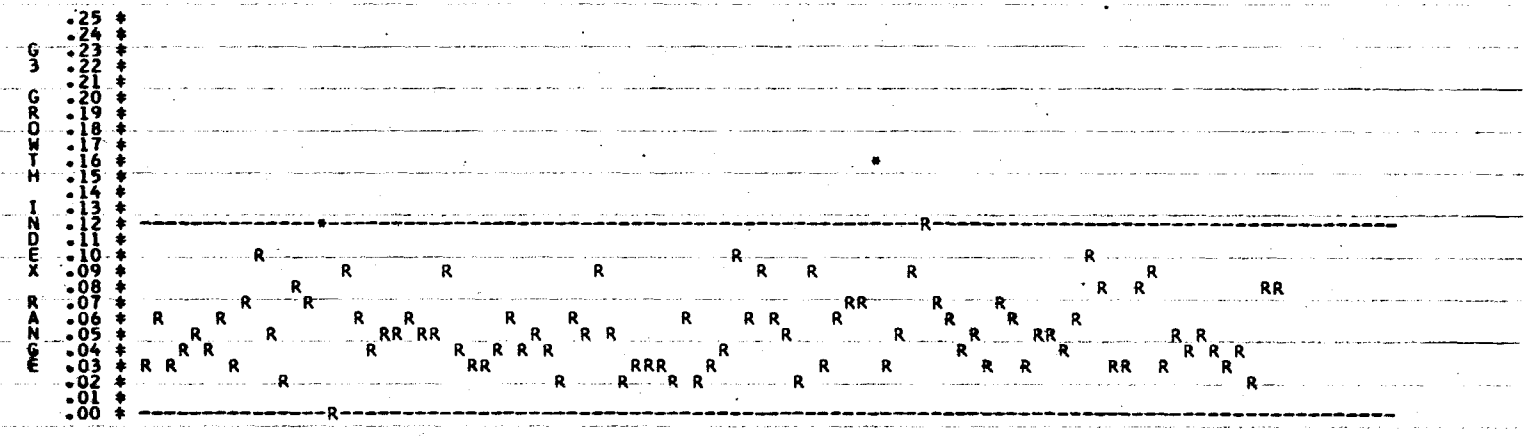
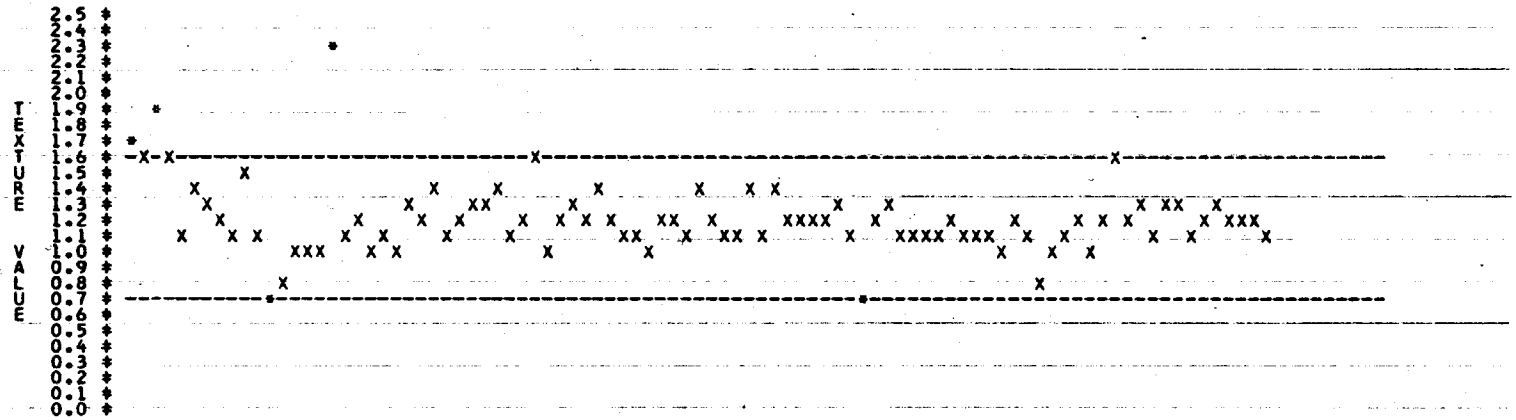


SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A SCNC ROUTINE PRODUCTION SLUGS
020 CRYSTALLOGRAPHIC PLANE TEXTURE
CIRCUMFERENTIAL DIRECTION SAMPLES



X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES

APR 61 MAY 61 JUN 61 JUL 61 AUG 61 SEP 61 OCT 61 NOV 61 DEC 61 JAN 62 FEB 62 MAR 62 APR 62 MAY 62 JUN 62 JUL 62

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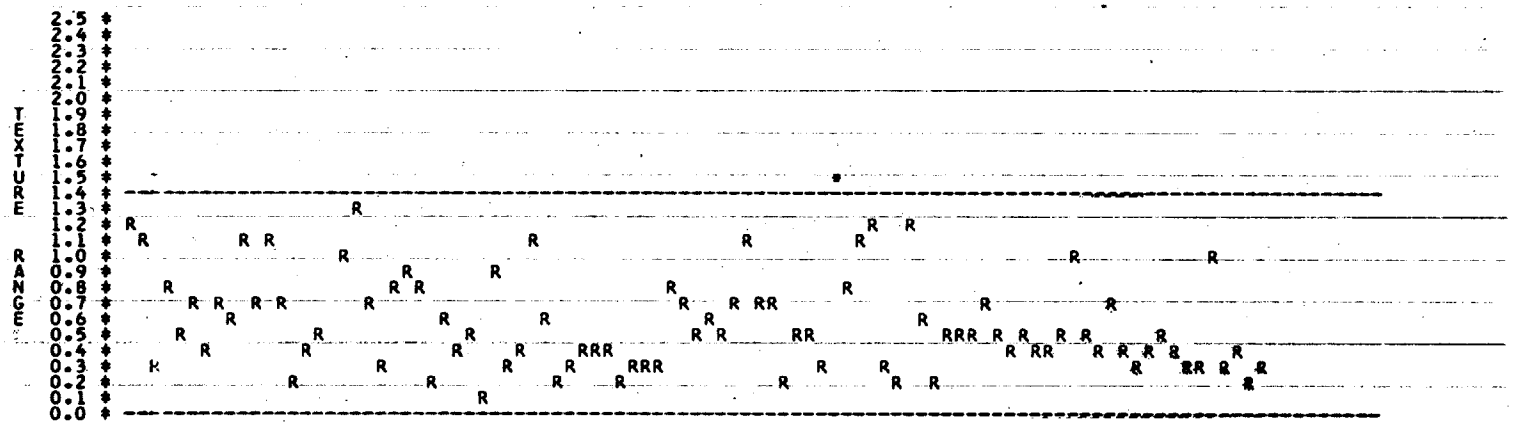
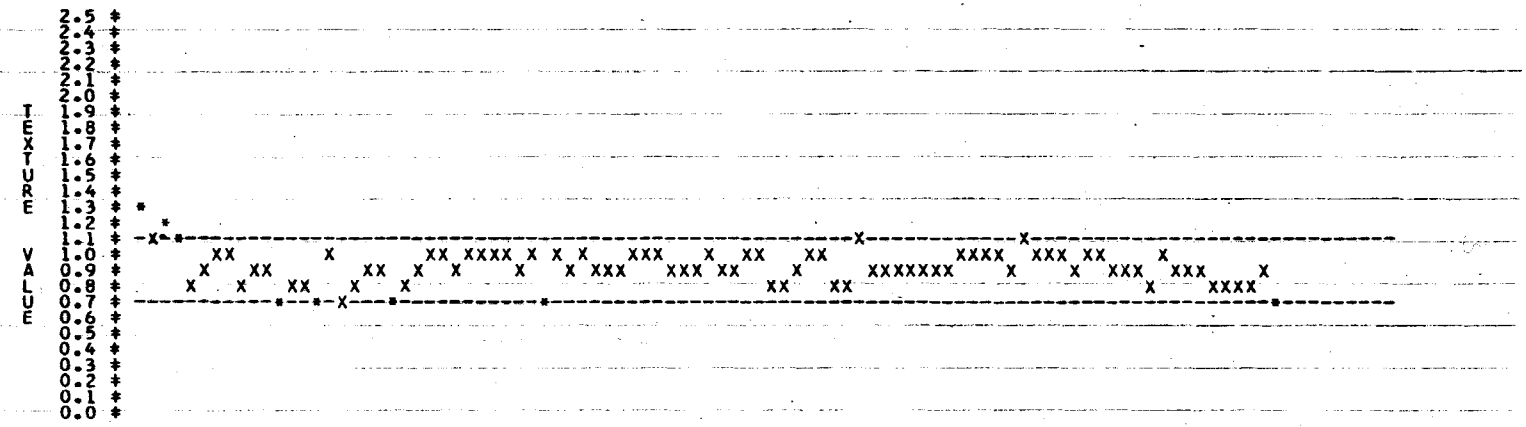


SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A SCNC ROUTINE PRODUCTION SLUGS
110 CRYSTALLOGRAPHIC PLANE TEXTURE
CIRCUMFERENTIAL DIRECTION SAMPLES



X IS THE ARITHMETIC MEAN OF FOUR SEQUENTIAL SAMPLES

APR 61 MAY 61 JUN 61 JUL 61 AUG 61 SEP 61 OCT 61 NOV 61 DEC 61 JAN 62 FEB 62 MAR 62 APR 62 MAY 62 JUN 62 JUL 62

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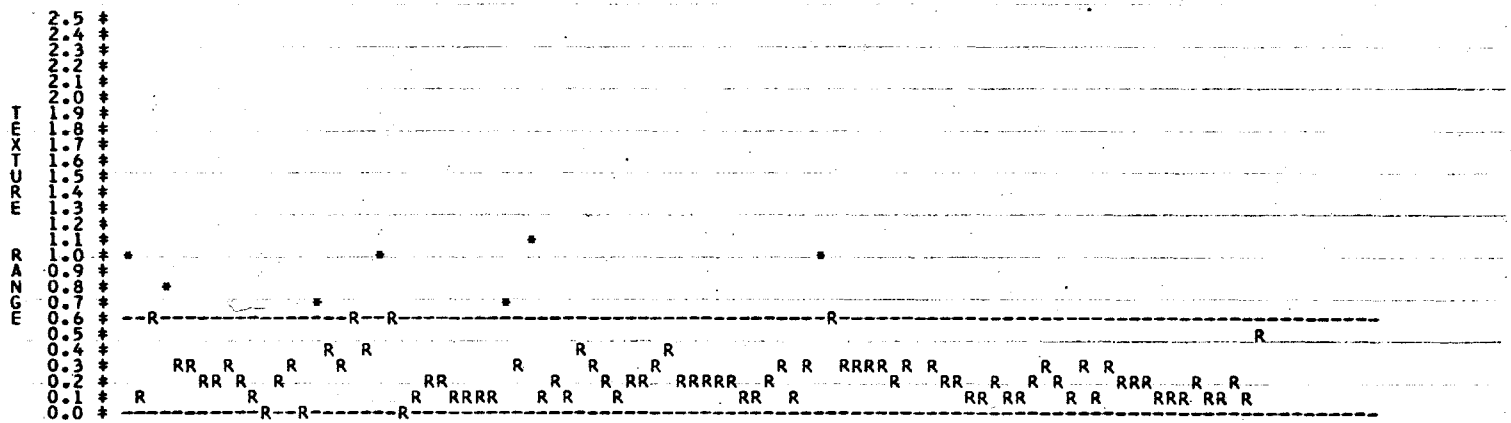
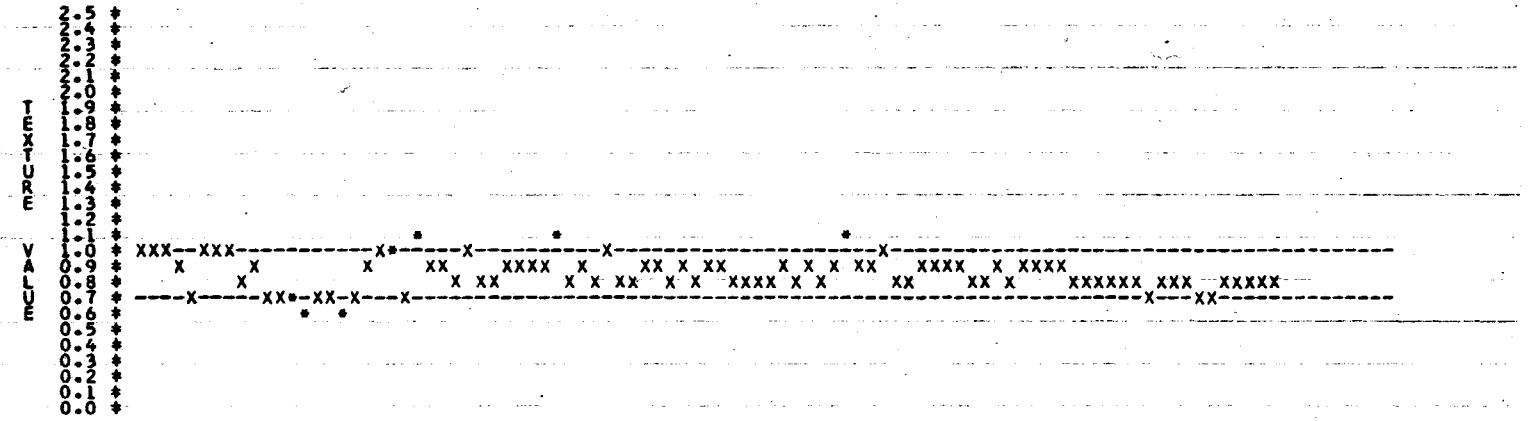


SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A SCNC ROUTINE PRODUCTION SLUGS
021 CRYSTALLOGRAPHIC PLANE TEXTURE
CIRCUMFERENTIAL DIRECTION SAMPLES



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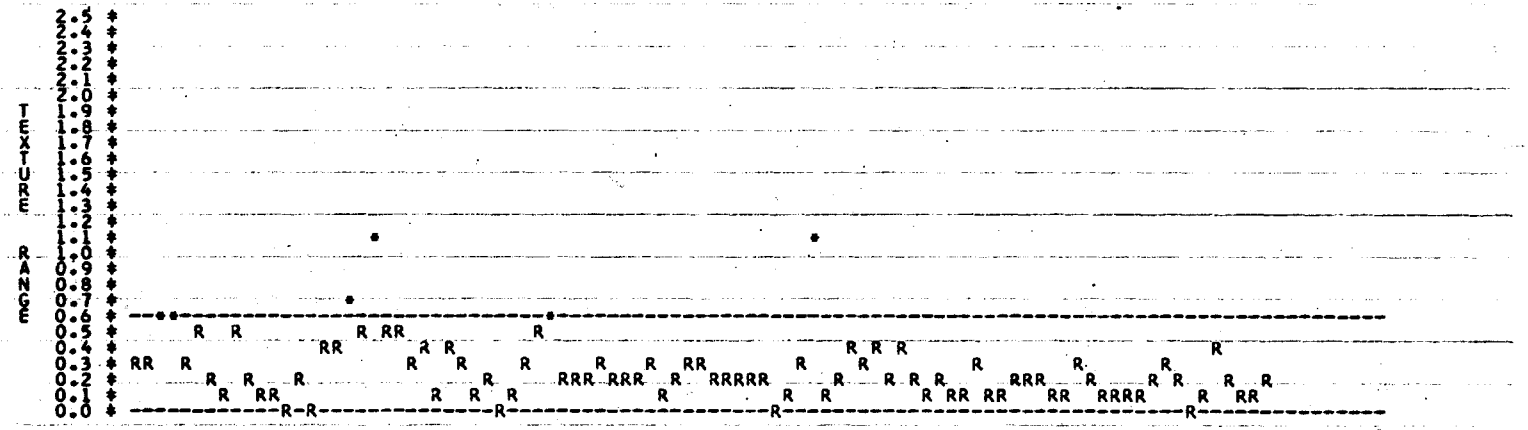
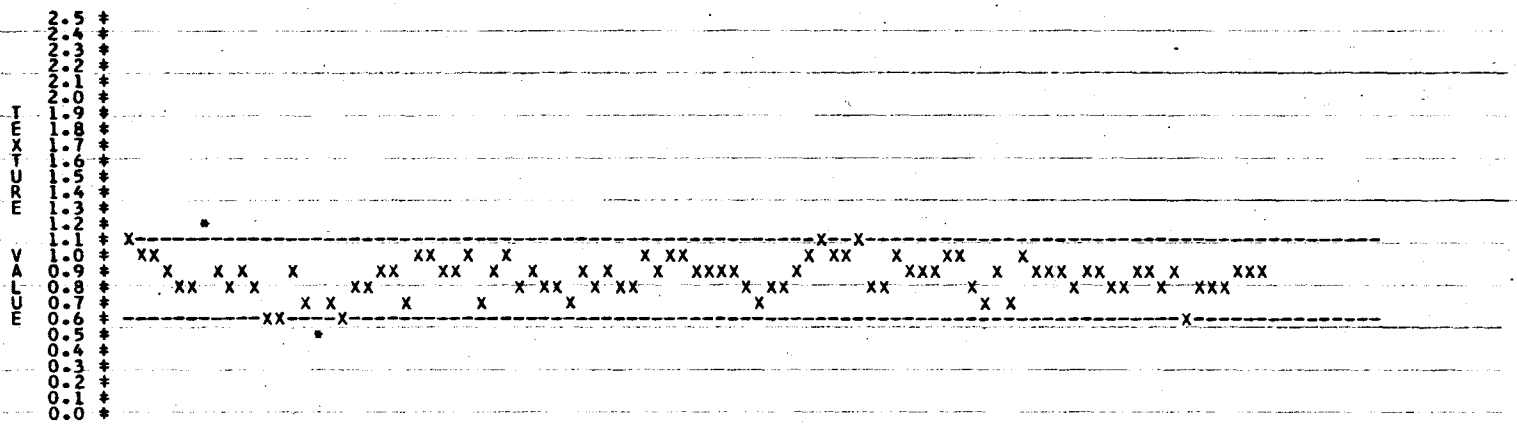


SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A SCNC ROUTINE PRODUCTION SLUGS
002 CRYSTALLOGRAPHIC PLANE TEXTURE
CIRCUMFERENTIAL DIRECTION SAMPLES



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APR 61	MAY 61	JUN 61	JUL 61	AUG 61	SEP 61	OCT 61	NOV 61	DEC 61	JAN 62	FEB 62	MAR 62	APR 62	MAY 62	JUN 62	JUL 62

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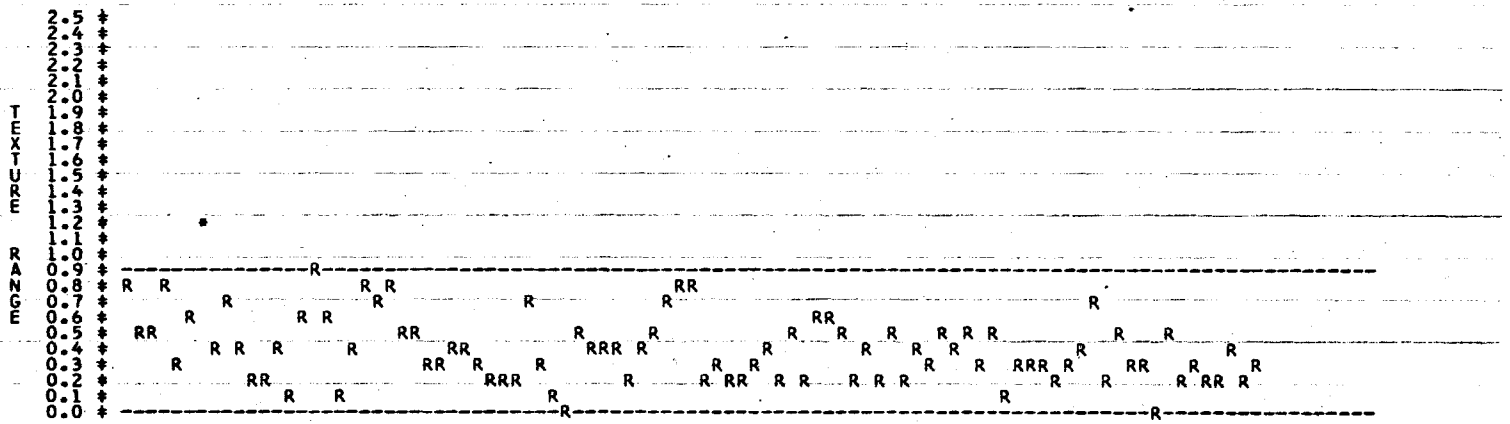
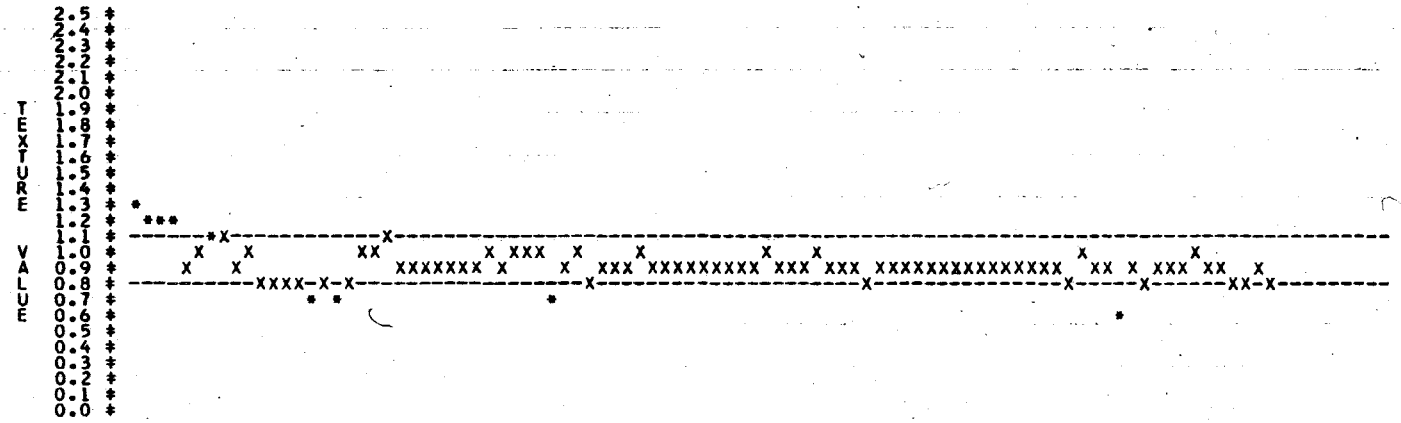


SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A SCNC ROUTINE PRODUCTION SLUGS
111 CRYSTALLOGRAPHIC PLANE TEXTURE
CIRCUMFERENTIAL DIRECTION SAMPLES



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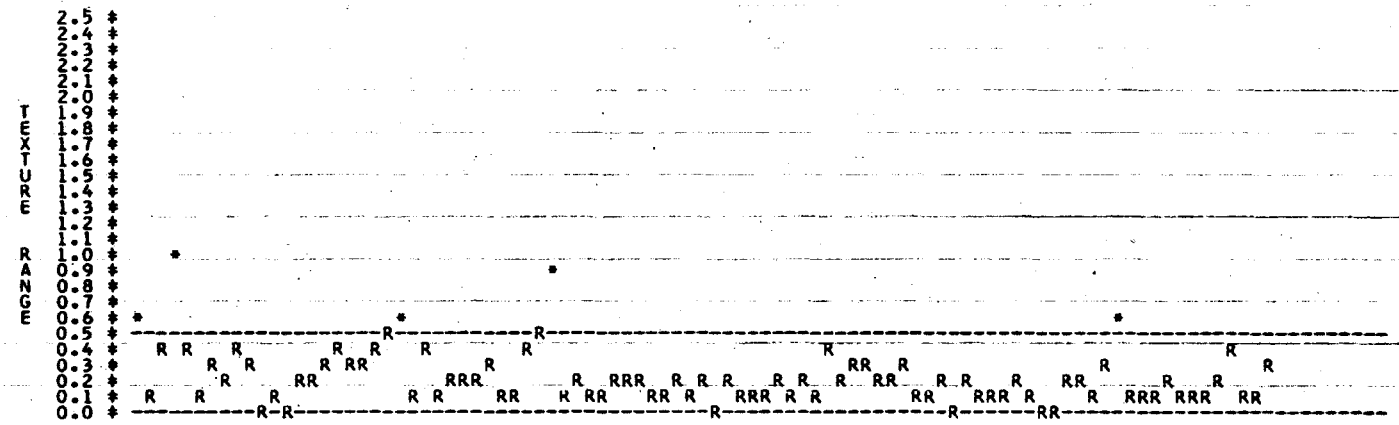
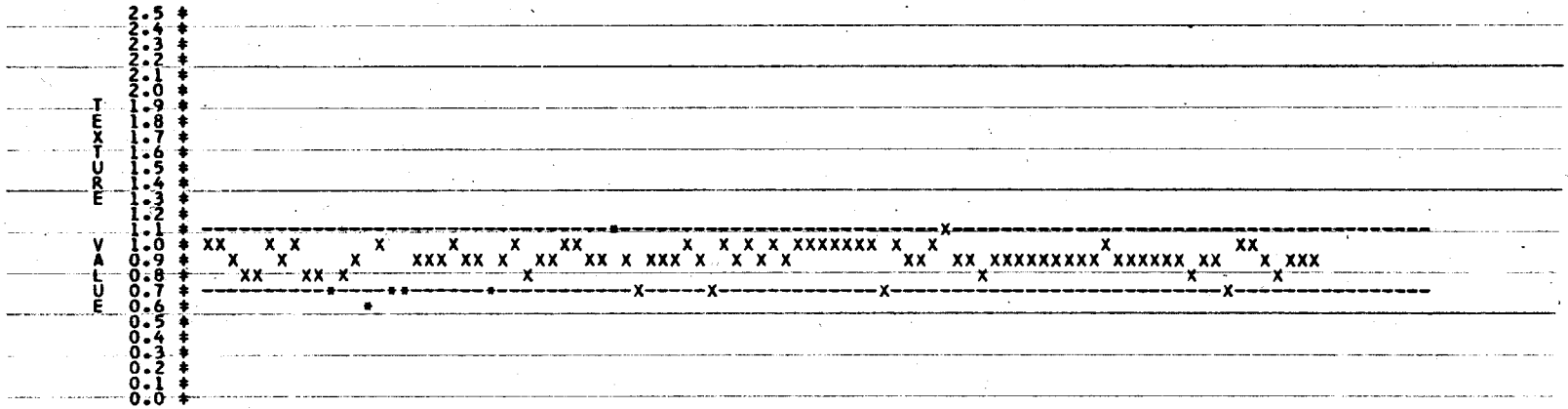


SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A SCNC ROUTINE PRODUCTION SLUGS
112 CRYSTALLOGRAPHIC PLANE TEXTURE
CIRCUMFERENTIAL DIRECTION SAMPLES



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APR 6 1 MAY 6 1 JUN 6 1 JUL 6 1 AUG 6 1 SEP 6 1 OCT 6 1 NOV 6 1 DEC 6 1 JAN 6 2 FEB 6 2 MAR 6 2 APR 6 2 MAY 6 2 JUN 6 2 JUL 6 2

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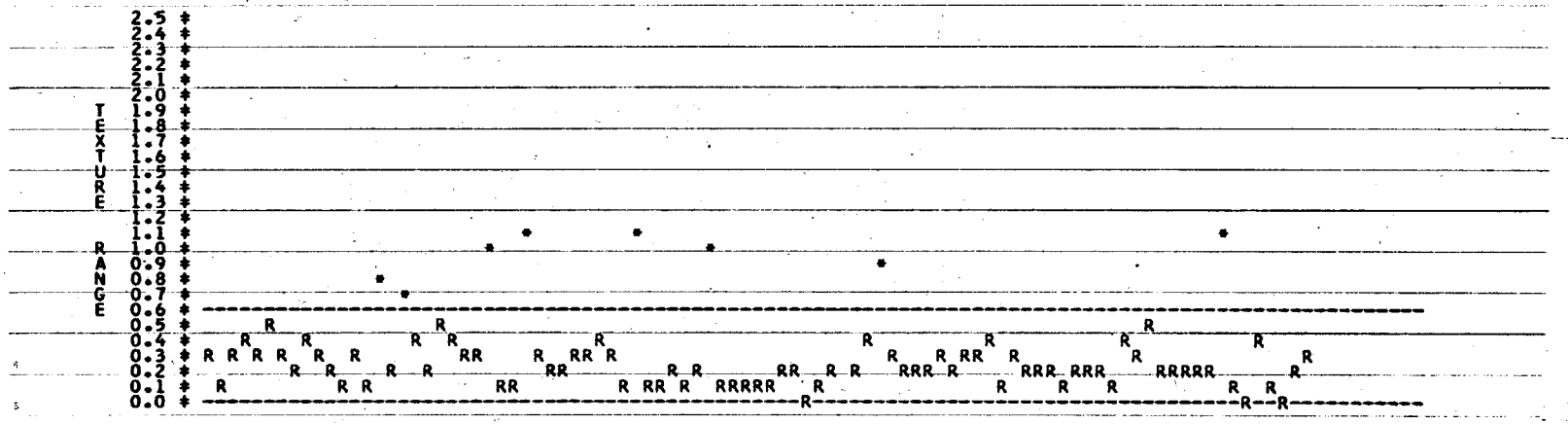
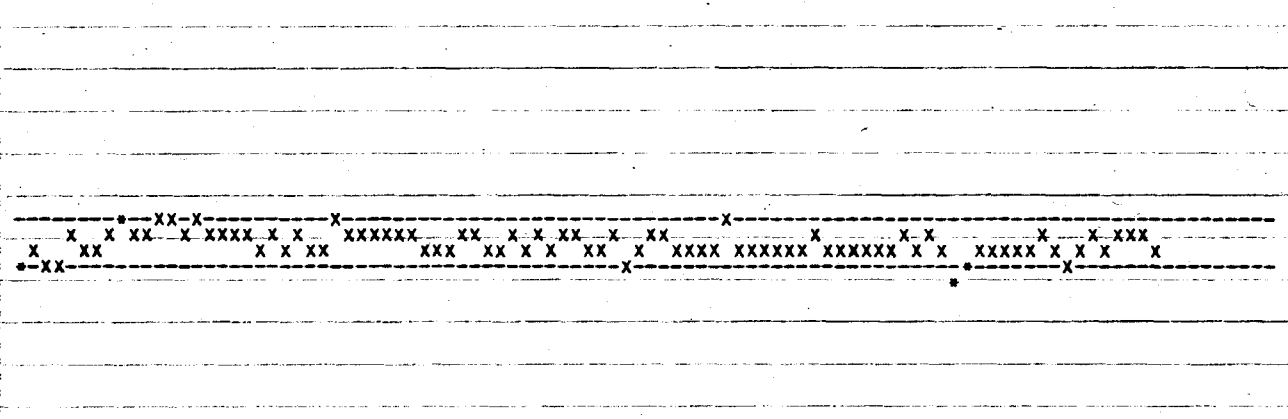


SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A SCNC ROUTINE PRODUCTION SLUGS
131 CRYSTALLOGRAPHIC PLANE TEXTURE
CIRCUMFERENTIAL DIRECTION SAMPLES



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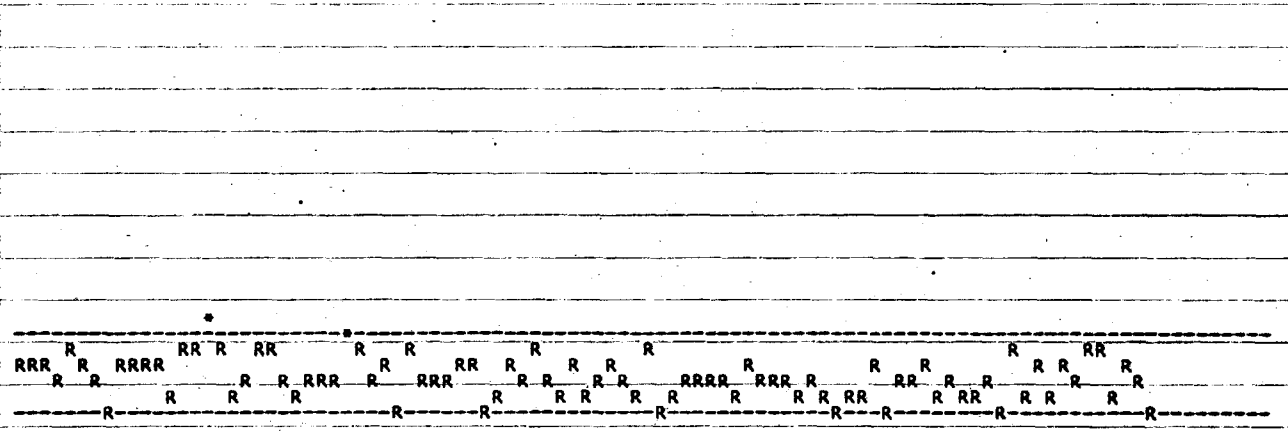
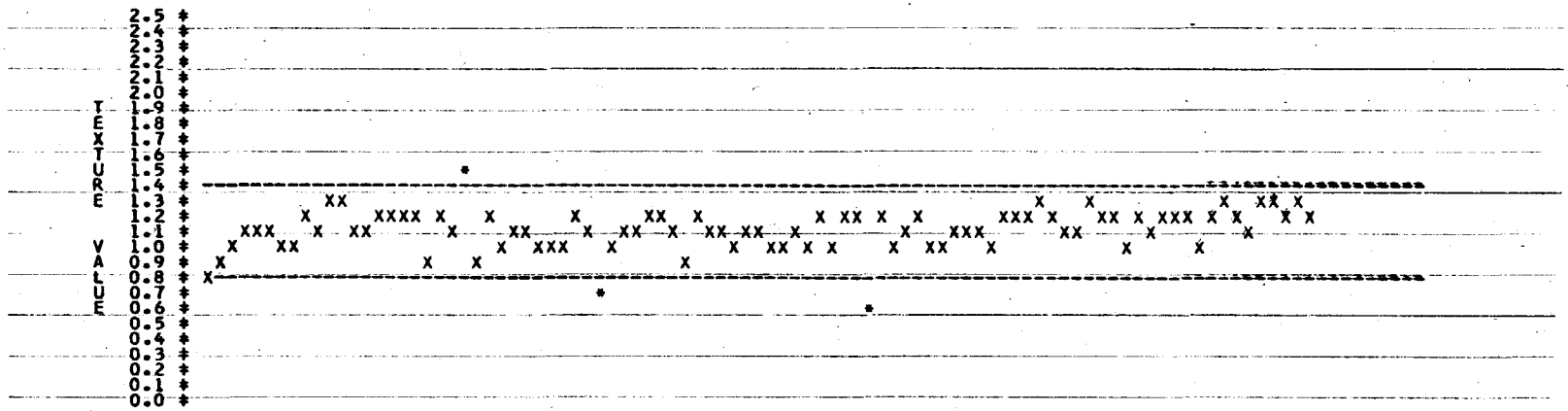


SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A SCNC ROUTINE PRODUCTION SLUGS
023 CRYSTALLOGRAPHIC PLANE TEXTURE
CIRCUMFERENTIAL DIRECTION SAMPLES



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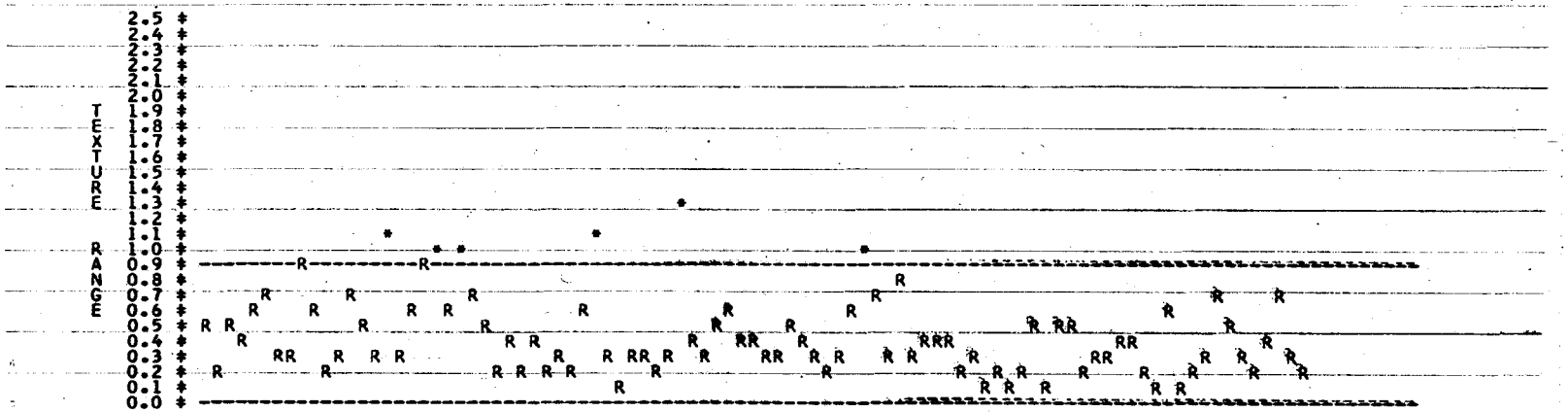
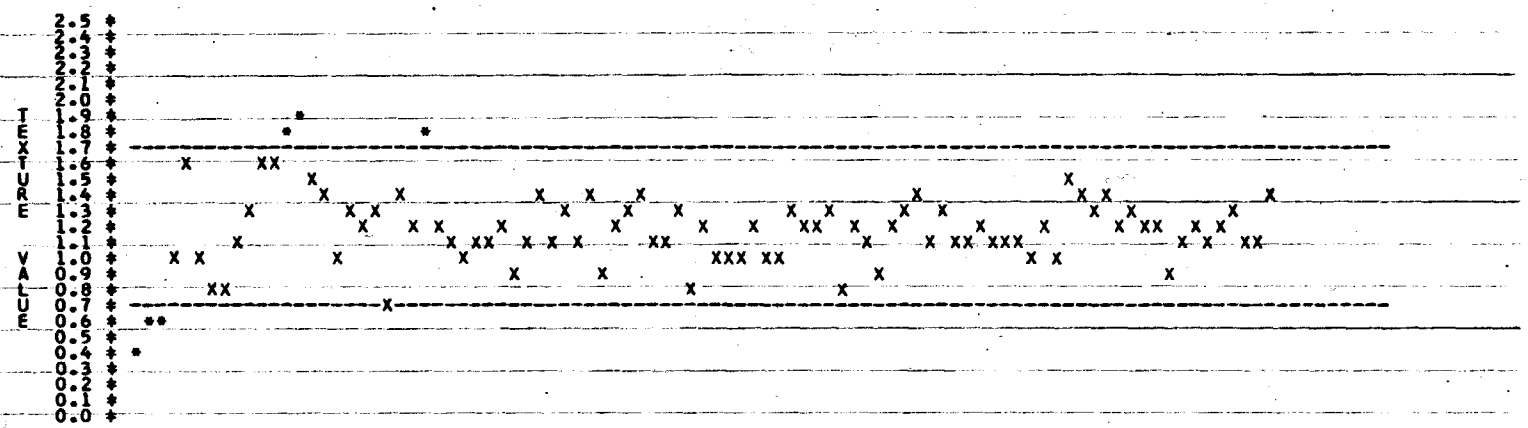


SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A SCNC ROUTINE PRODUCTION SLUGS
200 CRYSTALLOGRAPHIC PLANE TEXTURE
CIRCUMFERENTIAL DIRECTION SAMPLES



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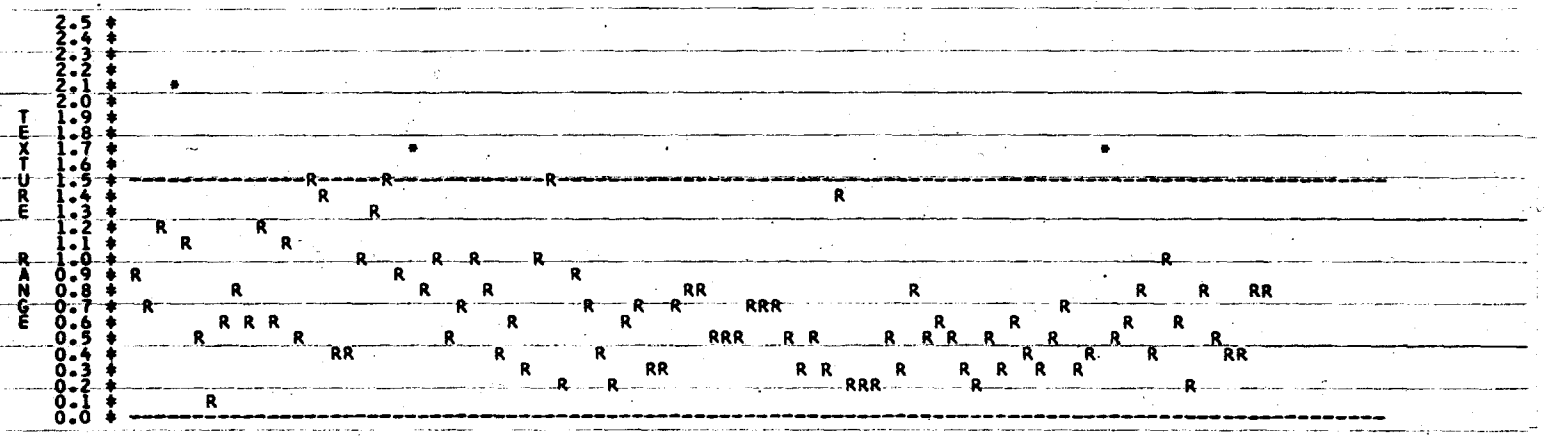

SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A SCNC ROUTINE PRODUCTION SLUGS
113 CRYSTALLOGRAPHIC PLANE TEXTURE
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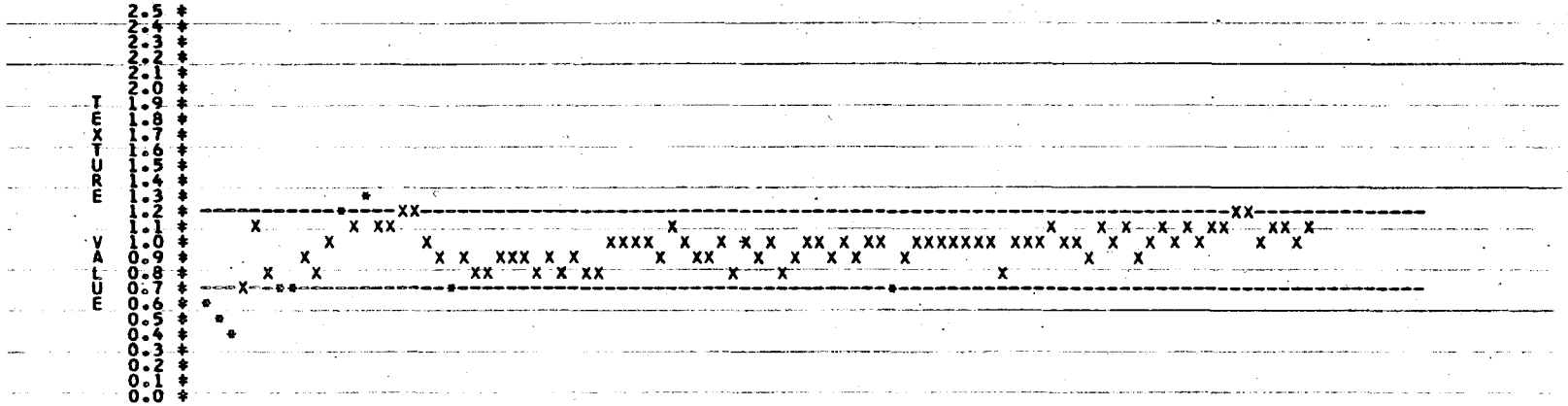

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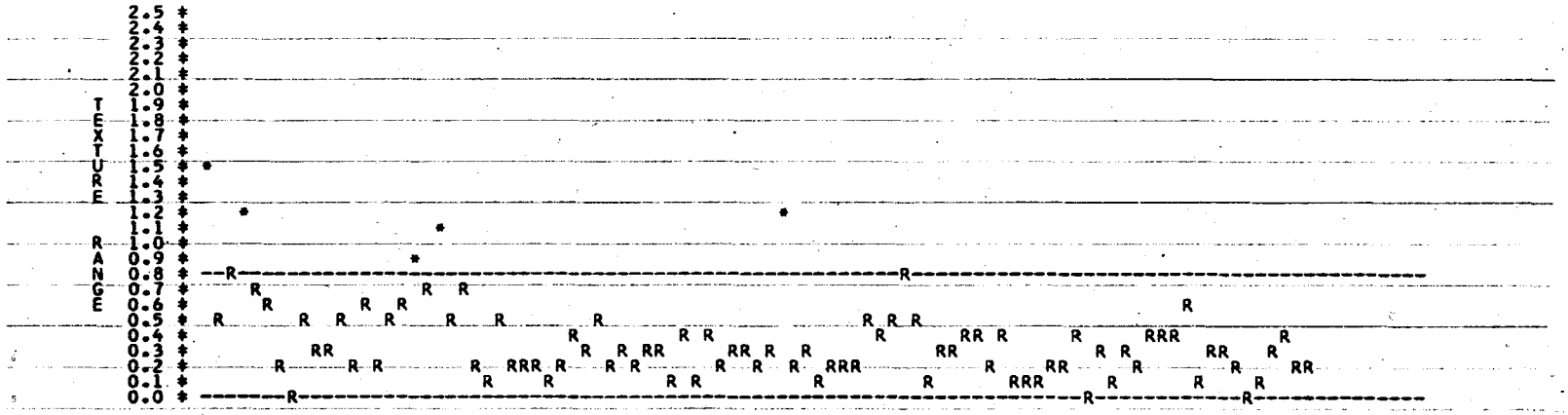
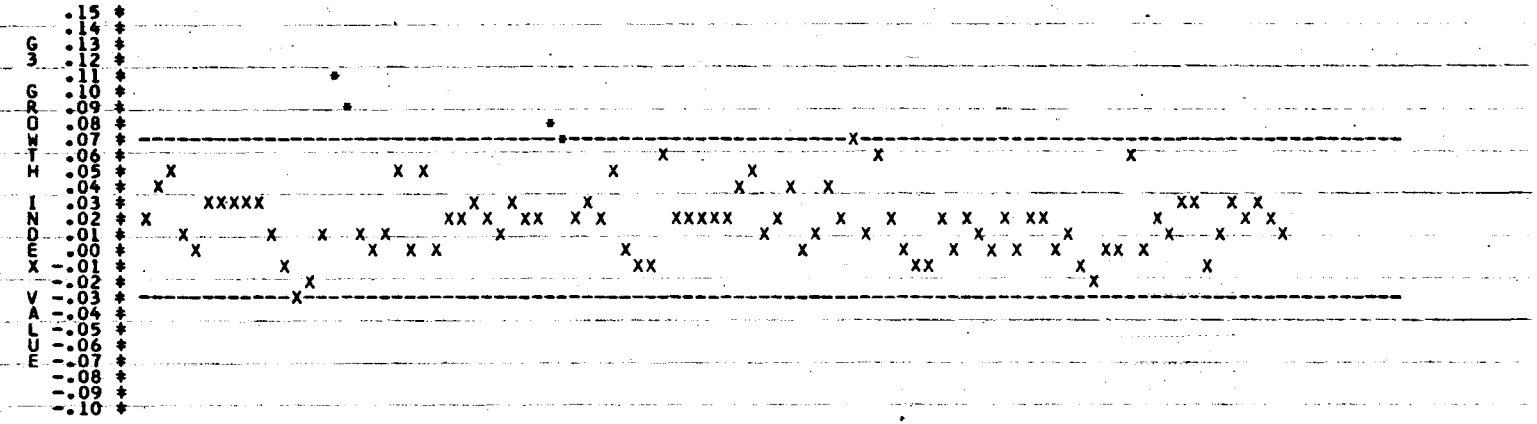


SAVANNAH RIVER PLANT
PREFERRED ORIENTATION SAMPLING
MARK VII-A SCNC ROUTINE PRODUCTION SLUGS
G3 AREA WEIGHT GROWTH INDEX
CIRCUMFERENTIAL DIRECTION SAMPLES



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